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Dean of Graduate Studies and Research

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ABSTRACT

Cephalometric head films from a sample of 35 patients who had undergone a LeFort I maxillary osteotomy combined with a simultaneous mandibular advancement were evaluated to determine the postsurgical stability of the skeletal segments. Twenty-six of the patients had rigid fixation to stabilize the segments and nine patients had skeletal wire fixation. Twenty-seven cephalometric parameters were examined before surgery, immediately after surgery, and after a follow-up period averaging fifteen months. The results showed the maxilla to be stable for both types of fixation but the mandible was significantly more stable in the rigid fixation sample, especially in terms of the ability of rigid fixation to maintain rotational control between the proximal and distal segments. Measurements of cephalometric points representing resting muscle lengths indicated a propensity for the stretched muscles to relapse back to within 5 percent of their original lengths. Both groups showed a long term change in the hyoid bone position and head posture.

ACKNOWLEDGEMENTS

I would like to thank my mentor, Dr. Peter Sinclair, for the countless hours he patiently guided and supported my efforts. His dedication to his residents and to the profession is an inspiration.

I would like to thank Dr. Larry Wolford who opened his office to me and was always available for assistance and advice. My association with him has left me with a deep appreciation for his skill and dedication.

For the unique opportunity to study Orthodontics here at Baylor, I must thank Dr. C. Moody Alexander and Dr. Robert Gaylord. It has been a wonderful and rewarding experience.

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DEDICATED TO

My Wife, Janet,

My Parents: Donald and Mildred Satrom

and

My Brothers and Sister

whose support, love and acceptance have sustained

and challenged me throughout my life

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VERSUS SKELETAL WIRE FIXATION

A THESIS SUBMITTED TO THE FACULTY OF

BAYLOR UNIVERSITY

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE

BY

KIRK D. SATROM, D.D.S.

DALLAS, TEXAS

AUGUST, 1988

CHAPTER I

INTRODUCTION

The advent of orthognathic surgery gave the practicing orthodontist, in conjunction with the oral surgeon, the ability to address skeletal deformities that had previously been treated by orthodontics alone. Often these orthodontic treatment results were unsatisfactory since they required severe dental compensations to accommodate the poor skeletal relationship, but with the recent advances in orthognathic surgery it has become possible for the surgeon to address many deformities that were previously untreatable. Long term stability following these surgical procedures has been of major concern since the early days of orthognathic surgery because the final long term result, both esthetic and functional, is directly related to the postsurgical stability.

The early studies of mandibular advancements (Poulton and Ware 1971, 1973) and maxillary LeFort I osteotomies (Wilmar 1974) revealed that mandibular relapse tended to be greater than maxillary relapse. Many studies of stability in the 1970's concentrated on mandibular advancements utilizing follow-up cephalometric radiographs in an attempt to identify the relapse patterns and their etiology (McNeill, Hooley and Sundberg 1973; Ive, McNeill and West 1977; Kohn 1978). These studies, as well as studies in the early 1980's (Schendel and Epker 1980; Lake et al. 1981), demonstrated that relapse primarily occurred during intermaxillary fixation and immediately following the release of fixation, so that the long term results were not always predictable. Some studies of the relapse patterns following maxillary LeFort I osteotomies were reported during this period (Schendel et al. 1976; Hedemark and Freihofer 1978) and demonstrated greater overall stability than seen for mandibular advancements but documented instances of instability for individual patients. In the late 1970's further advances in surgical techniques allowed surgical procedures to be performed in both the maxilla and the mandible simultaneously. Early studies of double jaw surgery reported lesser amounts of mandibular relapse and greater maxillary relapse than for single jaw procedures performed independently (Brammer et al. 1980)

Numerous theories regarding the primary etiologic causes of relapse have been advanced and studied. These include: (1) stretching of the muscles of mastication and the suprahyoid musculature (Poulton and Ware 1973; McNamara et al. 1978), (2) condylar distraction during surgery (Epker, Wolford and Fish 1978; Schendel and Epker 1980; Worms et al. 1980), (3) counter-clockwise rotation of the mandible (Poulton and Ware 1973; Epker et al. 1978), and (4) rotational position changes between the proximal and distal segments (Lake et al. 1981; Reitzik 1980).

Simultaneously, various surgical techniques and postsurgical therapies were advocated in order to minimize relapse and numerous studies were conducted to evaluate their results. These techniques included suprahyoid myotomies (Steinhauser 1973; Epker et al. 1978; Ellis and Carlson 1983) and cervical collars (Poulton and Ware 1973; Brammer et al. 1980) utilized to reduce muscle tension following surgery.

Numerous fixation techniques have been advocated to reduce relapse postsurgically. These have included: (1) upper and lower border wiring of the mandible (Booth 1981), (2) Steinman pins to stabilize the maxilla (Bennett and Wolford 1985), (3) skeletal wire fixation (Schendel and Epker 1980), and (4) rigid fixation (Champy et al. 1978). Studies involving mandibular advancements alone (Ellis and Gallo 1986; Thomas et al. 1986) and maxillary LeFort I procedures alone (Luyk and Ward-Booth 1985) have indicated a strong potential for reduced relapse using the two most popular of these alternate techniques: skeletal wire fixation and rigid fixation. These fixation techniques have yet to be evaluated for double jaw surgery.

None of the above studies have directly compared results of skeletal wire fixation and rigid fixation using a carefully selected sample, so that statistical comparisons between the stability of the fixation methods could be obtained. In fact, to date no cephalometric study of either fixation technique has been conducted for double jaw surgery. Thus, the purpose of this study was to compare the stability of rigid fixation versus skeletal wire fixation. A sample of patients who had undergone the same surgical procedure (maxillary impaction with a simultaneous mandibular advancement) was carefully selected from the office of one surgeon. Evaluations of cephalometric values representing skeletal segment movements, dental movements, muscle changes and postural changes, both during surgery and postsurgically, were utilized to compare the fixation techniques and to test the validity of some of the current relapse theories.

CHAPTER II

REVIEW OF THE LITERATURE

Vertical maxillary excess (VME) combined with mandibular deficiency has been reported as the most common Class II malocclusion (LaBanc, Turvey and Epker 1982). A LeFort I osteotomy to impact the maxilla combined with a simultaneous mandibular advancement is a commonly recommended procedure to correct this malocclusion (Bell, Jacobs and Quejeda 1986; Bell, Sinn and Finn 1982). The ability to minimize postsurgical skeletal and dental relapse and accurately predict its amount and duration is an important element in the achievement of the desired treatment result (Wolford, Hilliard and Dugan 1984), but unfortunately, maxillary impaction combined with mandibular advancement has been reported as being the most unstable type of bimaxillary surgical procedure (Doyle 1986). Studies have shown the potential for large amounts of skeletal and associated dental relapse both during intermaxillary fixation (McNeill et al. 1973; Schendel and Epker 1980) and following intermaxillary fixation release (Kohn 1978; and Lake et al. 1981).

Mandibular Advancement Studies with Wire Osteosynthesis

Early stability studies by Poulton and Ware (1971, 1973) on a small number of well documented cases involving mandibular advancement surgery only showed skeletal relapse ranging from 23 percent to 76 percent of the surgical advancement. This was confirmed by McNeill et al. (1973) who indicated that from 30 percent to 60 percent of anteroposterior (AP) relapse could occur during the intermaxillary fixation. In a long term study with an average follow-up of two years, Kohn (1978) reported a mean anteroposterior relapse of 17 percent during the fixation period and a 23 percent relapse postfixation. In a long term study on 52 patients, Lake et al. (1981) reported that skeletal relapse occured in 79 percent of the patients during fixation with a mean horizontal relapse of 26 percent of the surgical advancement. Postfixation relapse was reported to be variable and not significant. The skeletal relapse reported has been accompanied by associated compensating dental changes so that the relapse tendency is not always apparent as a change in occlusal relationships (McNeill et al. 1973; Kohn 1978; Lake et al. 1981). However, all of the studies mentioned so far have involved mandibular advancement surgery only.

Maxillary LeFort I Studies with Wire Osteosynthesis

Studies evaluating postoperative relapse following LeFort I osteotomies are less numerous than those concerning mandibular advancement and most of the LeFort I studies are concerned primarily with anteroposterior rather than vertical changes. Wilmar (1974) demonstrated minor postoperative changes in the position of the maxilla following LeFort I osteotomies in 106 patients but only three of her patients were treated by superior repostioning of the maxilla. Schendel et al. (1976) reported on 30 patients treated surgically to correct vertical maxillary excess. Although relapse was not reported as a percentage of the operative movement, it was indicated that the segments were stable showing a mean relapse of 1.2 mm at A-point. Hedemark and Freihofer (1978) reported that downgrafting of the maxilla had a strong tendency for relapse whereas impaction of the maxilla tended to be much more stable. A more recent study of 26 patients who underwent superior positioning of the maxilla (Greebe and Tuinzing 1987) showed the procedure to be very stable demonstrating no relapse. An excellent study by Proffit, Phillips and Turvey (1987) with 61 patients showed a tendency for continued superior repositioning of the maxilla during fixation followed by an inferior relapse pattern after the release of fixation. It should be noted that these studies utilized interosseous wiring and intermaxillary fixation as their primary mode of fixation. Generally, although the studies of maxillary impaction are few in number, the data on LeFort I osteotomies used alone to correct vertical maxillary excess appear to demonstrate reasonable stability, especially in relation to the greater amounts of relapse reported for mandibular advancements.

Double Jaw Surgery Studies with Wire Osteosynthesis

Only a few studies have reported on the stability of orthognathic surgery involving the mobilization of both jaws simultaneously to correct vertical maxillary excess combined with mandibular retrusion. A study by Brammer et al. (1980) on a limited number of patients showed a 12 percent vertical relapse of the maxilla and only a 14 percent anteroposterior mandibular relapse. LaBanc et al. (1982) reported on the results of 44 patients who underwent double jaw surgery to correct VME and mandibular deficiency and indicated the results were stable but gave no data concerning the amount of relapse. In an excellent study of 12 patients who underwent mandibular advancements simultaneously with maxillary procedures, Wade (1988) used tantalum implants to document relapse. He reported an average AP relapse of 27 percent in the mandible, of which 19 percent occurred during the fixation period. No maxillary relapse values were reported. Two recent studies utilizing an amorphous sample of patients whose double jaw surgery involved a number of different procedures (maxillary impaction, downgrafting, advancement and setback plus mandibular advancement or setback), reported that the maxilla appeared to be less stable if a mandibular procedure was done concomitantly (Iannetti, Chimenti and DiPaolo 1987) and that any maxillary relapse occurred within the first five months post-operatively (Carlotti and Schendel 1987).

Investigations Concerning the Etiology of Relapse

The studies discussed above for the most part utilized wire osteosynthesis combined with intermaxillary fixation to stabilize the surgical segments. The poor stability seen, especially for mandibular advancement surgery alone, has generated much discussion concerning the etiology of relapse. At the same time various surgical techniques and postsurgical regimens have been proposed to improve the stability. Epker et al. (1978) in their discussion of diagnostic considerations for mandibular advancement surgery listed the following potential causes of relapse: (1) failure to orthodontically place the teeth over basal bone, (2) improper seating of the condyle at the time of surgery, (3) effects of stretching the muscles of mastication and the suprahyoid musculature, (4) counterclockwise rotation of the mandible during surgery, and (5) the type of fixation. Many authors have implicated muscle lengthening as a cause of relapse (McNamara et al. 1978; Poulton and Ware 1973; Ellis and Carlson 1983). An often quoted statement from the 1978 article by Epker et al. is that "...muscles can be 'stretched' or lengthened approximately 15 percent of their resting length ..." and that they will not tolerate greater lengthening. More recently work by Carlson, Ellis and Dechow (1987) indicated that the muscle belly itself only stretches minimally and that the adaptations take place primarily at the muscle-tendon interface. Other authors have implicated condylar distraction (Epker et al. 1978; Schendel and Epker 1980; Worms et al. 1980) or condylar remodeling (Nickerson and Moystad 1982) as etiologic agents in mandibular relapse. Counterclockwise rotation of the mandible has also been mentioned as cause of relapse (Epker et al. 1978; Poulton and Ware 1973) as have rotational position changes between the proximal and distal segments (Reitzik 1980). Epker and Wessberg (1982) in a thorough overview of skeletal relapse potential stated that good surgical technique including "prolonged skeletal stabilization with control of the proximal segment of the mandible" was the best way to ensure predictable stability. Worms et al. (1980) also stated that proper fixation to ensure proper condylar position was the key to stability.

Alternative Fixation Techniques to Wire Osteosynthesis

Several types of alternative wire fixation methods have been proposed and studied for mandibular advancement procedures in recent years. An upper and lower border wiring technique proposed by Booth (1981) was studied by Smith, Maloney and West (1985) using 50 patients with a six week postsurgical follow-up. They reported a relapse of 30 percent in the horizontal projection of gnathion and a relapse of 8 percent in the mandibular corpus length. These values are similar to those reported for other wiring techniques confined to the mandible.

Alternative fixation methods such as (1) bone grafting (Araujo et al. 1978; Garrison, Lapp and Bussard 1987), (2) skeletal fixation (Epker and Wessberg 1982) and (3) threaded Steinmann pins for skeletal fixation (Wolford and Hilliard 1981) have also been recommended for use with LeFort I osteotomies. All of the studies of these techniques have involved maxillary advancement and/or maxillary downgrafting rather than maxillary impaction, but the authors have indicated that improved stability was achieved by these methods.

Skeletal Fixation versus Rigid Fixation

In recent years, two main alternatives to wire osteosynthesis combined with intermaxillary fixation have been advocated: skeletal fixation and rigid fixation. Skeletal fixation uses wires or pins to connect the surgical segments to other parts of the facial skeleton rather than only to the teeth. Rigid fixation utilizes plates and screws to fix the surgical segments to each other and to unoperated areas of the facial skeleton.

Skeletal fixation using circummandibular wires secured to infraorbital or circumzygomatic wires has been suggested to minimize relapse following mandibular advancement (Schendel and Epker 1980). This method was studied by Ellis and Gallo (1986) in 20 individuals and by Mayo and Ellis (1987) in an experimental study using the Macaca mulatta monkey. Both studies reported improved stability over wire osteosynthesis with this method of fixation. Ellis and Gallo (1986) reported relapse figures of 9 percent of the surgical movement while Mayo and Ellis (1987) reported no relapse in their group of twelve experimental animals.

Many authors (VanSickles and Jeter 1985; Spiessl 1982; Hedemark and Freihofer 1978) have advocated the use of rigid fixation by means of plates and screws to stabilize the osteotomy segments in order to achieve increased stability. Plate and screw osteosynthesis has been used by orthopedic surgeons to reduce fractures in long bones for many years and has been popularized for facial procedures in the last few years by Champy et al. (1978), Horster (1980), Drommer and Luhr (1981), and Spiessl (1982). This type of rigid fixation has included small L or T shaped moldable plates which are placed across the osteotomy sites in the maxilla, and fixed to the movable and the fixed portions of the skeleton by small, self-tapping screws. In the mandible it has been more common to use two or three self-tapping lag type screws to fix the two overlapping portions of the proximal and distal segments which have been separated by a sagittal split ramus osteotomy technique. It has been stated that this type of fixation has a reduced tendency for relapse (Spiessl 1982) due to the primary bone healing provided by cortex to cortex approximation (Reitzik 1983; Reitzik and Schoorl 1983), and thus the ability to resist the possible relapse-producing forces of the musculature and scar contracture. Other advantages listed include a reduction in the period required for intermaxillary fixation from four to six weeks to one to three days and an improved ability to place the condyle in a passive position in the glenoid fossa (Van Sickels and Flanary 1985).

Only a few studies have explored the stability of rigid fixation. As with wire osteosynthesis, the majority of these studies have dealt with mandibular advancement surgery only. Paulus and Steinhauser (1982) reported more stable results using rigid fixation. In 1985, on a sample of nine patients, Van Sickels and

Flanary (1985) showed an increase in the horizontal projection of B pt. by 1.1 mm during a six to eight month follow-up using rigid fixation. Thomas et al. (1986), in an excellent study, demonstrated less relapse using rigid fixation compared to wire osteosynthesis (10 percent for rigid vs. 24 percent for wire), and Van Sickels, Larsen and Thrash (1986) found a only a 0.3 mm (6 percent) relapse following mandibular advancement with rigid fixation. Other recent studies published by Barer et al. (1987), Kirkpatrick et al. (1987) and McDonald et al. (1987) based on sample sizes ranging from 20 to 43 patients have reported mandibular relapse ranging from 6 percent to 16 percent using rigid fixation. All these values are much less than those reported using wire osteosynthesis and, depending upon the study, are equal to or better than those reported for skeletal fixation.

Several articles have also recently appeared reporting on the stability of the maxilla following LeFort I procedures stabilized with plates and screws. Luyk and Ward-Booth (1985), reporting on 11 patients, showed good stability in the anteroposterior direction but did report a continued movement of A pt. inferiorly by 0.9 mm after a minor downgrafting of 0.7 mm. Other reports by Persson, Hellem, and Nord (1986) and by Harsha and Terry (1986) on vertical maxillary deficient patients who underwent maxillary downgrafting procedures indicated that rigid fixation produced stability equal to or better than wire osteosynthesis. In these studies the results were extremely variable from patient to patient. However, to date no study on VME patients who have undergone maxillary impaction with rigid fixation is available.

The reports cited above indicate the potential for improved stability utilizing rigid fixation or skeletal fixation, especially in the mandible. Unfortunately, no report currently exists in the literature comparing rigid fixation using plate and screw osteosynthesis to skeletal wire fixation in double jaw surgery cases for any specific classification of dentofacial deformity. Doyle (1986) did review his experiences with rigid versus wire osteosynthesis but the sample, which included some double jaw surgery patients, did not have a large enough number of patients in any one category to draw statistical conclusions. Therefore, this study is designed to compare rigid versus wire osteosynthesis with skeletal fixation for a specific and common dentofacial deformity requiring double jaw surgery, the Class II patient with vertical maxillary excess.

CHAPTER III

MATERIALS AND METHODS

The patients in both the rigid fixation sample and the skeletal wire fixation sample were selected from the records of one surgeon, Dr. Larry Wolford of Dallas, Texas. The samples consisted of 26 patients for the rigid fixation sample and nine patients for the skeletal wire fixation sample (Table 1) that met the following strict criteria:

1. All patients must have had a presurgical diagnosis of Vertical Maxillary Excess (VME) and mandibular deficiency.

2. The surgical procedure must have consisted of double jaw surgery with a LeFort I osteotomy to correct the vertical maxillary excess and a bilateral sagittal split ramus osteotomy to correct the mandibular deficiency.

3. The maxillary surgery could have involved one, two, three, or four segments, but no additional

TABLE 1.--Comparison of Rigid versus Skeletal Wire Fixation Samples

VARIABLE	RIGID FIXATION	SKELETAL FIXATION
1. Number Patients	26	9
2. Number Females	18	7
3. Number Males	8	2
4. Mean Age (Yrs.)	30.2	20.8
5. Age Range (Yrs.)	15 - 50	16 - 36
6. Mean Presurgical Ceph (Days)	4.1	12.7
7. Mean Postsurgical Ceph (Days)	1.8	2.2
8. Mean Follow-up Ceph (Months)	15.0	15.2
9. Range Follow-up Ceph (Months)	8 - 24	8 - 24
10. Number 1 Pc. Maxillas	6	3
11. Number 3 Pc. Maxillas	19	6
12. Number 4 Pc. Maxillas	1	0
13. Number Proplast Chins	12	1
14. Number Bony Chins	1	1
15. Number with no Chin	13	7

mandibular procedures such as a body osteotomy could have been performed.

4. No temperomandibular joint surgery could have been performed either at the time of the orthognathic surgery, less than six months prior to the orthognathic surgery, or during the follow-up period.

5. Presurgical, immediate postsurgical, and follow-up lateral cephalometric radiographs must be available and the follow-up cephalometric radiographs must have been taken at least six months after the orthognathic surgery.

6. Orthodontics to correctly prepare the patient for surgery and finalize the occlusion must have been included in the treatment.

7. The patients must have been non-growing during the evaluation period as demonstrated by no significant increase in the length of the mandible or the distance from sella to nasion.

The patients in the rigid fixation sample had a similar surgical treatment procedure using a LeFort I step osteotomy in the maxilla as described by Bennett and Wolford (1985) and the segments were stabilized by means of Wurzburg or Champy mini-plates and screws. A minimum of four plates were placed with two screws on each side of the surgical bony cut for stabilization. Additional plates were used as needed depending upon the number of maxillary segments. The mandibular procedure was performed using a modification of the sagittal split ramus osteotomy as described by Wolford, Bennett and Rafferty (1987) with two to three 2 mm bicortical bone screws placed per side. The period of intermaxillary fixation ranged from zero to three days.

The patients in the skeletal wire fixation sample also had a LeFort I osteotomy combined with a bilateral sagittal split ramus osteotomy in the mandible. In the skeletal fixation sample, the maxillary procedure did not include the step osteotomy since that technique had not been developed at that time. In this sample, stabilization was achieved by means of intraosseous wiring in the maxilla and superior border wiring in the mandible. Intermaxillary fixation plus vertical infraorbital suspension wires and circummandibular wires completed the skeletal stabilization. The period of intermaxillary fixation ranged from four to six weeks.

Each of the presurgical (T1), immediate postsurgical (T2) and follow-up (T3) lateral cephalometric radiographs was traced by one individual. There were 28 points identified (Table 2 and Figure 1) and 27 cephalometric parameters were measured (Table 3), of which eight were angular and 19 were linear. In order to ensure that each point was accurately placed in the same anatomical location for each successive radiograph, the points were marked on the T1 tracing and then regional superimpositions for the areas of the cranial base, maxilla, mandibular body, mandibular ramus, hyoid bone or cervical vertebrae were utilized to accurately locate the points on the tracings for times T2 and T3.

In order to quantify the horizontal and vertical movements of the maxilla, the mandible and th^ hyoid bone, the tracings were overlayed on a coordinate system with an origin at Sella and an x axis was constructed six degrees clockwise from the S-N line. The horizontal and vertical projections of A Pt., PNS, B Pt. and the hyoid reference point to the x and y axes were then marked on the tracing. The linear measurements were

TABLE 2.--Cephalometric Points Recorded

1. Sella
2. Nasion
3. A Pt.
4. Posterior Nasal Spine
5. Apex - Upper Incisor
6. Incisal Edge - Upper Incisor
7. Incisal Edge - Lower Incisor
8. Apex - Lower Incisor
9. B Pt.
10. Menton
11. Anterior Digastric Point
12. Anterior Mylohyoid Point
13. Posterior Mylohyoid Point
14. Gonion
15. Articulare
16. Posterior Digastric Point
17. Occiput
18. Atlas
19. Cervical Vertebrae #1
20. Hyoid
21. Hyoid Horizontal (Constructed)
22. B Pt. Horizontal (Constructed)
23. A Pt. Horizontal (Constructed)
24. PNS Horizontal (Constructed)
25. Hyoid Vertical (Constructed)
26. PNS Vertical (Constructed)
27. B Pt. Vertical (Constructed)
28. A Pt. Vertical (Constructed)

FIGURE 1.--Cephalometric Points Recorded

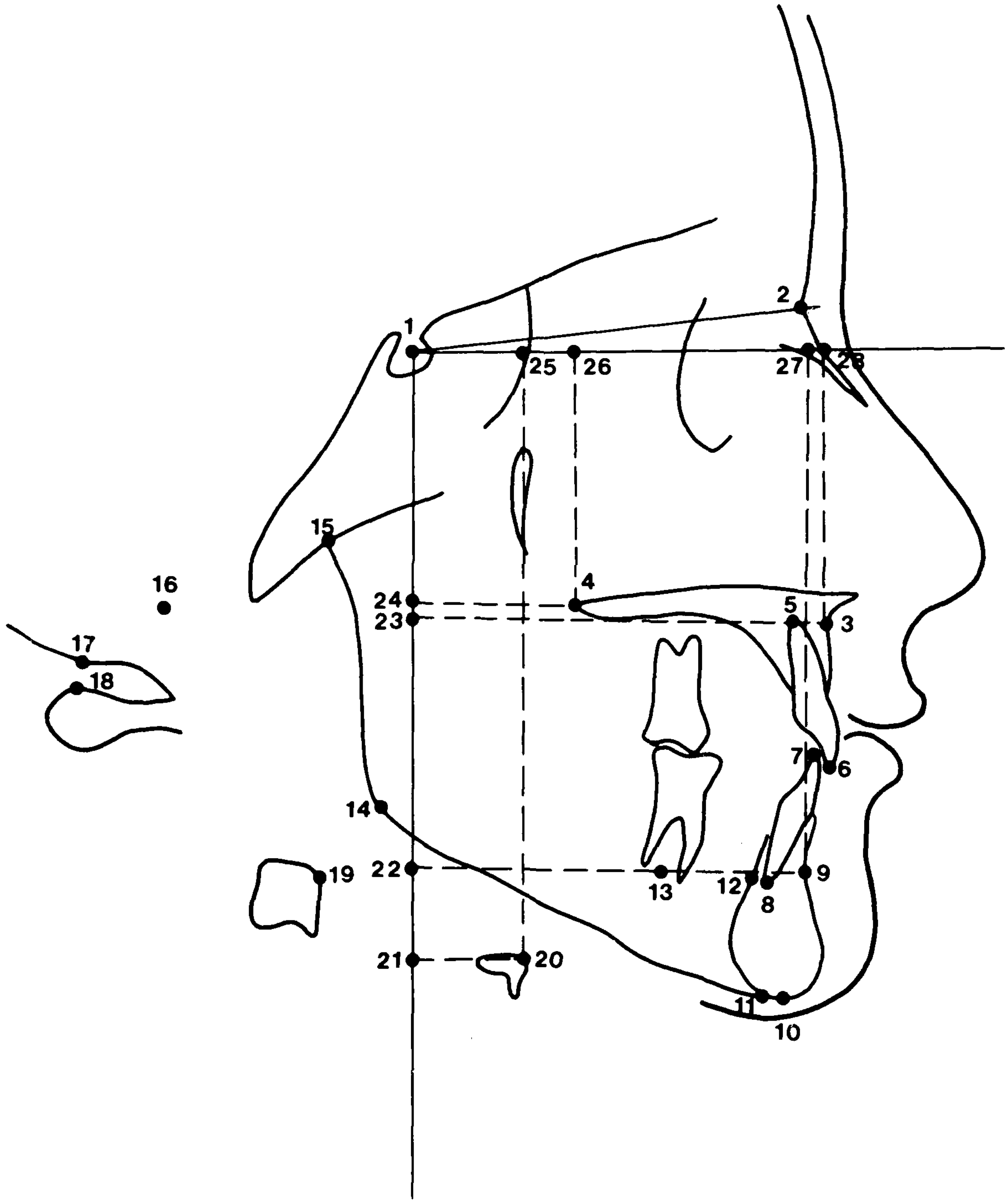
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TABLE 3.-- Cephalometric Measurements

	DESCRIPTION	PTS. USED	
1.	SNA Angle	1-2-3	deg
2.	SNB Angle	1-2-9	deg
3.	ANB Angle	3-2-9	deg
4.	Mandibular Plane Ang.	1-2 W/ 14-10	deg
5.	Proximal Segment Ang.	1-2 W/ 15-14	deg
6.	Goniol Angle	15-14-10	deg
7.	Upper Incisor to SN	1-2 W/ 5-6	deg
8.	Lower Incisor to MP	7-8 W/ 14-10	deg
9.	Sella to Nasion	1-2	mm
10.	A Pt. to A Pt. Hor.	3-23	mm
11.	A Pt. to A Pt. Vert.	3-28	mm
12.	PNS to PNS Hor.	4-24	mm
13.	PNS to PNS Vert.	4-26	mm
14.	B Pt. to B Pt. Hor.	9-22	mm
15.	B Pt. to B Pt. Vert.	9-27	mm
16.	Mand. Body Length	14-10	mm
17.	Mand. Total Length	15-10	mm
18.	Proximal Seg. Length	15-14	mm
19.	Post. Facial Height	1-14	mm
20.	Post. Digastric Lngth	16-20	mm
21.	Ant. Digastric Length	20-11	mm
22.	Post. Mylohyoid Lngth	20-13	mm
23.	Ant. Mylohyoid Length	20-12	mm
24.	Hyoid to Hyoid Hor.	20-21	mm
25.	Hyoid to Hyoid Vert.	20-25	mm
26.	Cerv. Vert. 1 to Hyoid	19-20	mm
27.	Occiput to Atlas	17-18	mm

made using a digital micrometer[1] which measured to the nearest 0.01 mm. All values were rounded to the nearest 0.1 mm. All angular measurements were measured to the nearest one-half of a degree using a cephalometric protractor.[2] Ten tracings were selected at random and remeasured to determine the measurement error. The distance from sella to nasion was also measured as a check to ensure no magnification differences had occurred from one film to another and to ensure no growth had occurred during the follow-up period. When the ten tracings were remeasured, no individual value differed from the previously measured value by more than 0.3 mm for the linear measurements or 1.0 degree for the angular measurements. The difference between the means for the two separate measurements averaged less than 0.1 mm for the linear measurements and 0.2 degrees for the angular measurements. The check on magnification error revealed minimal to no magnification as indicated by the

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[1]Fowler Ultra-Cal II, Fred V. Fowler Co., Inc., Newton, MA 01266

[2]Baum Cephalometric Protractor, Unitek Corporation, Monrovia, CA 91016

fact that the value of the sella to nasion distance did not vary by more than 0.3 mm from one film to another.

All data was listed on a predesigned form and then entered into a database management program[3] where the surgical changes and the follow-up changes were calculated (surgical change : T2 value - T1 value, follow-up change : T3 value - T2 value). A positive surgical or follow-up value indicated an anterior movement in the horizontal direction or an inferior movement in the vertical direction. This data was then transferred to a spreadsheet program[4] where the following statistical analyses were performed. The means and standard deviations were calculated for each variable for each time period within each group and also for the surgical and follow-up changes within each group. In order to determine whether the surgical changes and the follow-up changes within each group were statistically significant, a two tailed Student's t-Test for the difference between the means of the two

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[3]dBASE III, Ashton Tate Corp., Cambridge, MA 02142

[4]Lotus 1-2-3, Lotus Development Corp., Cambridge, MA 02142

matched samples was run from time T1 to T2 and from T2 to T3. A significance level of $p < 0.05$ was chosen. In order to determine whether the surgical changes and follow-up changes were statistically different for the two groups (rigid fixation versus skeletal wire fixation), a two tailed Student's t-Test for two independent samples was run at a significance level of $p < 0.05$. In addition a Pearson's Product-Moment coefficient of correlation was calculated to examine the relationship between: (1) the relapse values (follow-up changes) of a given variable and the surgical changes of that or other variables and (2) the relapse value of a given variable and the relapse values of other variables measured. A correlation value of less than 0.5 was considered no correlation. A correlation value of 0.5 to 0.6 was considered very weak, from 0.6 to 0.7 weak, from 0.7 to 0.8 moderate and a correlation value of greater than 0.8 was considered strong.

CHAPTER IV

RESULTS

The rigid sample was larger than the skeletal wire fixation sample (26 patients versus nine patients) but the two samples were remarkably similar in terms of their demographic data (Table 1, p. 21) and their initial cephalometric values (Table 4). The percentage of females was similar for both samples (70 percent for the rigid sample versus 78 percent for the skeletal wire sample), as was the mean follow-up period (15.0 months for the rigid sample versus 15.2 months for the skeletal wire sample). Although the mandibular plane angle to SN was slightly higher for the rigid sample than the skeletal wire sample (40.3 deg versus 38.2 deg), and the posterior facial height slightly smaller for the rigid sample (81.4 mm versus 84.3 mm for the skeletal wire sample); the other values were very similar. There were no significant differences between any of the initial cephalometric values for the two samples.

TABLE 4.--Rigid versus Skeletal Wire Fixation - Comparison of Initial (T1) Cephalometric Values

VARIABLE	Rigid Fixation	Skeletal Fixation	Sig.
1. SNA Angle (Deg)	77.9	78.8	N.S.
2. SNB Angle (Deg)	71.5	72.1	N.S.
3. ANB Angle (deg)	6.4	6.8	N.S.
4. Man. Plane Angle (deg)	40.3	38.2	N.S.
5. Post. Facial Ht. (mm)	81.4	84.3	N.S.
6. Man. Total Length (mm)	105.9	106.6	N.S.
7. Upper 1 To SN (deg)	103.6	102.7	N.S.
8. Lower 1 TO MP (deg)	93.7	89.8	N.S.

N.S. = not significant

Rigid Fixation Sample

Rigid Sample - Anteroposterior Movement of the Maxilla

(Table 5: Measurements 1, 2 and 3)

Evaluating the anteroposterior surgical change in the maxilla, there was a small but significant increase in the SNA angle (1.4 deg $\pm$ 2.0, $p < .01$) and a similar small forward horizontal movement of A pt. during surgery (1.9 mm $\pm$ 2.1, $p < .001$). This change was extremely stable with neither measurement showing any relapse (SNA relapse = 0.0 $\pm$ 0.9 deg., p: N.S.; A Pt. horizontal relapse = 0.0 $\pm$ 1.0 mm, p: N.S.). There were 18 of the 26 patients who showed less than 1 mm of relapse evenly distributed between further forward movement and backward relapse. There was no change during the follow-up period greater than 2.0 mm and there was no correlation between the amount of surgical movement and the amount of relapse.

A similar small forward surgical movement was seen when evaluating the posterior part of the maxilla (1.7 $\pm$ 3.0 mm, $p < .01$), and the posterior maxilla continued forward during the follow-up period another

TABLE 5.--Rigid Fixation Sample - Maxillary Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. SNA Angle	77.9	79.3	79.4	+1.4	**	0.0	N.S.
Std Dev (deg)	3.4	2.9	3.2	2.0		0.9	
2. A Pt Hor	68.4	70.3	70.3	+1.9	***	0.0	N.S.
Std Dev (mm)	6.9	6.2	6.3	2.1		1.0	
3. PNS Hor	28.7	30.4	30.8	+1.7	**	+0.4	N.S.
Std Dev (mm)	5.1	5.7	5.7	3.0		0.9	
4. A Pt Vert	55.2	52.6	52.7	-2.5	***	+0.1	N.S.
Std Dev (mm)	3.0	3.8	3.9	2.9		1.0	
5. PNS Vert	45.5	44.8	44.6	-0.6	N.S.	-0.2	N.S.
Std Dev (mm)	3.2	3.1	3.3	2.2		0.9	

+ = anterior or inferior
- = posterior or inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

0.4 ± 0.9 mm (p=N.S.). None of the relapse values for the maxilla in an anteroposterior direction were statistically significant.

Rigid Sample - Vertical Movement of the Maxilla

(Table 5: Measurements 4 and 5, p. 35)

The anterior part of the maxilla was impacted more than the posterior maxilla (-2.5 ± 2.9 mm, $p < .001$ versus -0.6 ± 2.2 mm, p: N.S.) and both were extremely stable over the follow-up period. The anterior maxilla relapsed downward only 0.1 ± 1.0 mm (p: N.S.) while the posterior maxilla continued to move superiorly another 0.2 ± 0.9 mm (p: N.S.). Eighteen of the 26 patients remained within 1 mm of the postsurgical position anteriorly and 19 of 26 stayed within 1 mm posteriorly. The maximum relapse in both cases was 2.1 mm in a superior direction. The sample was split equally in terms of superior versus inferior relapse in both the anterior and the posterior portions of the maxilla. Neither of the mean relapse values was statistically significant and there was no correlation between the amount of surgical movement and the amount of relapse in the vertical direction ($r = -0.16$).

Rigid Sample - Mandibular Movement Measured at B pt.

(Table 6: Measurements 1, 2, 3 and 4)

The average mandibular advancement in the horizontal direction was 8.6 ± 4.5 mm ($p < .001$) with the advancements ranging from 3.0 mm to 17.6 mm. This resulted in a +4.7 degree change in the mean SNB angle ($p < .001$) and a -3.3 degree change in ANB ($p < .001$). These changes were all very stable with the mean horizontal postoperative relapse being -0.5 ± 1.6 mm at B pt. (p: N.S.), only -0.4 ± 0.7 degrees ($p < .05$) in the SNB angle and $+0.4 \pm 1.1$ degrees (p: N.S.) in the ANB angle. Fifty percent of the patients remained stable within 1 mm of their postsurgical position. Five patients relapsed between 1 and 2 mm at B Pt., two patients between 2 and 3 mm, and two patients between 3 and 4 mm. The maximum relapse was -3.5 mm as measured at B Pt. Four of the patients had continued advancement of B Pt. beyond 1 mm in the horizontal direction. The

TABLE 6.--Rigid Fixation Sample - Mandibular Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. SNB Angle	71.5	76.2	75.9	+4.7	***	-0.4	*
Std Dev (deg)	3.0	3.1	3.0	2.4		0.7	
2. ANB Angle	6.4	3.1	3.6	-3.3	***	+0.4	N.S.
Std Dev (deg)	2.1	1.8	2.2	2.3		1.1	
3. B Pt Hor	52.5	61.0	60.6	+8.6	***	-0.5	N.S.
Std Dev (mm)	8.3	7.8	7.8	4.5		1.6	
4. B Pt Vert	96.6	95.2	95.0	-1.3	**	-0.2	N.S.
Std Dev (mm)	6.0	5.4	6.2	2.2		1.7	
5. Body Length	64.7	71.1	70.5	+6.4	***	-0.6	**
Std Dev (mm)	6.4	6.7	6.8	4.3		0.9	
(Go to Me)							
6. Total Length	105.9	111.7	111.0	+5.8	***	-0.7	**
Std Dev (mm)	7.1	6.8	6.9	3.2		1.1	
(Ar to Me)							
7. Prox Seg Ln	50.5	50.7	49.7	+0.2	N.S.	-1.0	***
Std Dev (mm)	6.1	6.1	6.0	1.1		1.1	
(Ar to Go)							

+ = anterior or inferior
- = posterior or inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

relapse in horizontal position of B Pt. demonstrated a strong correlation with the relapse in the SNB angle ($r = 0.85$). The relapse of ANB had a moderate correlation to the relapse of SNA ($r = 0.73$) and to the horizontal relapse of A Pt. ($r = 0.72$). There was no correlation between the amount of surgical movement and the amount of relapse for any of these variables.

The vertical change in the mandible as measured at B Pt. was only -1.3 ± 2.2 mm ($p < .01$). This small superior movement was extremely stable with a mean measured relapse of only -0.2 ± 1.7 mm (p: N.S.). The maxilla in 16 of the 26 patients continued to move superiorly after the surgery with a maximum vertical movement of -3.4 mm. Fifty percent of the patients remained within 1 mm of their postsurgical position. The relapse was not statistically significant and there was no correlation between the surgical movement of B Pt. in the vertical direction and its relapse ($r < 0.5$).

Rigid Sample - Changes in Mandibular Length

(Table 6: Measurements 5, 6, and 7, p. 38)

Evaluating the surgical changes by utilizing measurements within the mandible revealed a large and significant increase in both the total mandibular length as measured from articulare to menton (5.8 $\pm$ 3.2 mm, $p < .001$) and the mandibular body length as measured from gonion to menton (6.4 $\pm$ 4.3 mm, $p < .001$). The total length relapsed -0.7 $\pm$ 1.1 mm ($p < .01$) during the follow-up period and the body length relapsed -0.6 $\pm$ 0.9 mm ($p < .01$). Of the 26 patients, 14 maintained their mandibular total length within 1 mm of the postsurgical value. A similar degree of stability in the mandibular body length was seen for 17 of the 26 cases. The maximum value noted was -2.9 mm of relapse for total mandibular length and -2.5 mm relapse for mandibular body length. One patient showed an increase in total length and body length of 1.9 mm and 1.8 mm respectively in the postoperative period. There was only a weak correlation between the relapse of mandibular total length and mandibular body length (r = 0.68). A very weak correlation was found between the actual surgical increase in mandibular total length and its post-op relapse (r = -0.56). This correlation was weaker for mandibular total length (r = -0.44).

In an effort to evaluate the hypothesis that the potential for relapse increases in those cases with a greater amount of mandibular advancement, the sample was subdivided into those patients with less than 5 mm advancement (N = 12) and those with 5 mm or more advancement (N = 14) based upon the measurement of mandibular body length. The subset of patients with greater than 5 mm of advancement did show a significantly greater relapse than the subset with less than 5 mm of advancement when evaluated in terms of mandibular body length (-1.0 mm relapse versus -0.1 mm relapse, $p < .01$). The difference in the relapse between the two subsets was not as great when evaluated in terms of the mandibular total length (-1.0 mm versus -0.4 mm, p: N.S.) or in terms of the horizontal projection of B Pt. (-0.6 mm versus -0.3 mm, p: N.S.). When the six patients with advancements greater than 10 mm were separated into a subset, their relapse values were only slightly greater than those for the greater than 5 mm subset both in terms of mandibular body length (-1.2 mm versus -1.0 mm) and in terms of mandibular total length (-1.5 mm versus -1.0 mm).

The data showed that the proximal segment length as measured from articulare to gonion was increased a very small amount during surgery (0.2 $\pm$ 1.1 mm) and then decreased significantly during the post-op period (-1.0 $\pm$ 1.1 mm, $p < .001$). This resulted in a mean overall reduction of 0.8 mm in the length of the proximal segment. The immediate postsurgical proximal segment length was within 1 mm of its presurgical value in 19 of the 26 patients, was decreased just over 1 mm in one patient and was increased from 1 to 2.5 mm in the remaining six patients. The relapse in proximal segment length was 1 mm or less in 15 of the 26 patients. During the follow-up period the proximal segment length decreased in 20 of the 26 patients with a maximum decrease in length of -4.5 mm. There was a strong correlation between the decrease in proximal segment length and the decrease in posterior facial height (r = 0.90). A very weak correlation was found between the decrease in proximal segment length and its change during surgery (r = -0.54).

Rigid Sample - Changes in Mandibular Angular Measurements

(Table 7: Measurements 4, 5, and 6)

The three angular measurements within the mandible relate to the rotational changes within the mandible (gonial angle) and to the relation of the proximal and distal segments to the cranial base (proximal segment angle and mandibular plane angle). During surgery there was a decrease in the proximal segment angle as measured by the angle formed by the line from articulare to gonion with SN (-3.8 ± 4.0 deg., $p < .001$) and a decrease in the mandibular plane angle (-3.8 ± 3.0 deg., $p < .001$), indicating an autorotation type movement of the entire mandible. At the same time the gonial angle had a small decrease during surgery of -0.7 ± 3.7 degrees (p: N.S.) indicating a counterclockwise rotation of the distal segment with respect to the proximal segment within the mandible

TABLE 7.--Rigid Fixation Sample - Angular Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. SNA Angle	77.9	79.3	79.4	+1.4	**	+0.0	N.S.
Std Dev (deg)	3.4	2.9	3.2	2.0		0.9	
2. SNB Angle	71.5	76.2	75.9	+4.7	***	-0.4	*
Std Dev (deg)	3.0	3.1	3.0	2.4		0.7	
3. ANB Angle	6.4	3.1	3.6	-3.3	***	+0.4	N.S.
Std Dev (deg)	2.1	1.8	2.2	2.3		1.1	
4. Man Plane to SN	40.3	36.5	37.3	-3.8	***	+0.8	**
Std Dev (deg)	6.8	5.8	6.3	3.0		1.5	
5. Prox Seg to SN	88.5	84.7	84.6	-3.8	***	-0.7	N.S.
Std Dev (deg)	6.1	5.4	5.0	4.0		1.8	
6. Goniol Angle	133.5	132.8	134.3	-0.7	N.S.	+1.5	**
Std Dev (deg)	5.8	4.5	6.1	3.7		2.5	
7. Upper 1 to SN	103.6	103.6	102.4	0.0	N.S.	-1.1	N.S.
Std Dev (deg)	9.1	8.8	5.6	9.9		8.1	
8. Lower 1 to MP	93.7	92.9	91.2	-0.8	N.S.	-1.7	**
Std Dev (deg)	6.2	6.0	6.6	2.2		2.4	

+ = anterior or inferior
- = posterior or inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

itself. During the follow-up period the proximal segment angle continued to decrease a small amount (-0.7 ± 1.8 deg., p: N.S.) but, due to a clockwise relapse pattern in the gonial angle ($+1.5 \pm 2.5$ deg., $p < .01$), the mandibular plane angle to SN increased slightly ($+0.8 \pm 1.5$ deg., p <.0[illegible].

The proximal segment angle was decreased in all but two patients (range = -17.0 to +1.5 deg.) indicating a clockwise rotation of the proximal segment. The mandibular plane angle also showed a clockwise rotation pattern in all but one patient (range = -10.0 to +2.5 deg.) while the gonial angle was decreased in only 14 of the 26 patients (range = -8.0 to +5.5 deg.) The proximal segment angle continued to decrease during follow-up in 15 of the 26 patients (range = -4.0 to +2.5) with ten patients remaining within a degree of their postsurgical value. The mandibular plane angle tended to increase during the follow-up period with only eight patients showing a decrease (range = -2.5 to +3.5 deg.) and 13 of the patients staying stable within one degree of their postsurgical value. The gonial angle remained stable in more patients with 15 patients remaining within 1 degree and there was a ^rend for an increase in the gonial angle with only seven patients showing a decrease (range = -2.0 to +7.0 deg.).

There was no correlation between the amount of relapse and the amount of surgical change for any of the mandibular angles ($r < 0.5$). A weak positive correlation was evident between the relapse of the gonial angle and the relapse of the mandibular plane angle ($r = 0.64$), and a weak negative correlation was found between the relapse of the gonial angle and the relapse of the proximal segment angle ($r = -0.64$). The gonial angle also showed very weak correlations to the relapse of the posterior facial height ($r = -0.54$) and the relapse of the proximal segment length ($r = -0.61$).

<u>Rigid Sample - Changes in Incisor Angulation</u>

(Table 7: Measurements 7 and 8, p.44)

The upper incisor to SN angulation started at a mean value of 103.6 degrees and was unchanged following surgery (surgical change = 0.0 ± 9.9 deg., p: N.S.) while the lower incisor to mandibular plane angulation started at 93.7 degrees and was uprighted slightly during surgery (-0.8 ± 2.2 deg., p: N.S.). During the follow-up period the upper incisor angulation decreased slightly (-1.1 ± 8.1 deg. , p: N.S.) and the lower incisor angulation also decreased (-1.7 ± 2.4 deg., $p < .01$).

The change in upper incisor angulation was extremely variable with 15 of the 26 patients showing an increase in upper incisor angulation during surgery. The range of changes in angulation was from -17 degrees to +9.5 degrees. During the follow-up period the change in angulation was also quite variable. There were 17 of the 26 patients who had a decrease in angulation and the changes ranged from -10 to +7 degrees. The lower incisor angulation changes during surgery were less variable than for the upper incisor with a range of -5 degrees to +3.5 degrees. During the follow-up period, 17 of the patients experienced a decrease in the lower incisor angulation, three had no change and six showed a slight increase. The range was from +3 degrees to -6 degrees. There was no correlation between the relapse in angulation and the surgical change for either the upper or lower incisor and there was no correlation between these angulation changes and any other measurement ($r < 0.5$).

Rigid Sample - Changes in Muscle Length Measurements (Table 8: Measurements 1, 2, 3, 4 and 5)

Posterior facial height is included in this category since a change in posterior facial height would correspond to a change in the medial pterygoid and masseter muscle lengths. The mean posterior facial height was decreased a small but significant amount during surgery (-0.5 ± 1.2 mm, $p < .05$) and then decreased even further during the follow-up period (-1.0 ± 1.7 mm, $p < .01$). Posterior facial height was surgically decreased in 17 of the 26 patients and increased in the other nine (range = -3.0 mm to 1.8 mm). During the follow-up period it continued to decrease in 20 of the 26 patients with a maximum decrease of -6.0 mm. Posterior facial height increased in six of the patients in the follow-up period up to a value of 1.8 mm. Fifty percent of the patients remained within 1 mm of their postsurgical value. The relapse in posterior facial height showed a strong correlation to

TABLE 8.--Rigid Fixation Sample - Muscle Lengths, Hyoid Bone Position and Head Posture - Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. Post Fac Ht	81.4	80.9	79.9	-0.5	*	-1.0	**
Std Dev (mm)	8.0	7.9	8.0	1.2		1.7	
2. Post Digastic	89.4	97.4	90.0	+8.0	***	-7.4	***
Std Dev (mm)	10.1	10.6	10.5	4.9		4.6	
3. Ant Digastric	38.7	42.1	43.2	+3.4	**	+1.1	N.S.
Std Dev (mm)	7.6	5.6	6.1	5.9		3.5	
4. Post Mylohyoid	27.8	31.5	26.3	+3.7	***	-5.2	***
Std Dev (mm)	6.8	7.3	7.6	4.6		4.1	
5. Ant Mylohyoid	46.2	50.3	48.2	+4.1	***	-2.1	**
Std Dev (mm)	7.1	7.0	6.7	4.9		3.7	
6. Hyoid Horizontal	2.2	8.3	8.3	+6.1	***	0.0	N.S.
Std Dev (mm)	8.9	9.3	7.1	5.0		5.0	
7. Hyoid Vertical	108.8	114.3	106.2	+5.5	***	-8.1	***
Std Dev (mm)	10.6	11.6	12.3	4.5		4.6	
8. C1 to Hyoid	35.7	41.3	36.2	+5.6	***	-5.1	***
Std Dev (mm)	4.8	6.2	5.3	3.2		3.1	
9. Occ to Atlas	6.7	8.2	8.1	+1.5	**	-0.1	N.S.
Std Dev (mm)	3.5	3.1	3.0	2.2		2.0	

+ = anterior or inferior
- = posterior or inferior

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

the relapse in proximal segment length ($r = 0.90$) and a weak correlation to the relapse in the gonial angle ($r = -0.61$). The relapse showed no correlation to the surgical change ($r < 0.5$).

The digastric muscle lengths were both increased during surgery. The posterior digastric, as measured from the hyoid bone to the mastoid process was increased by 8.0 $\pm$ 4.9 mm ($p < .001$) and the anterior digastric was increased by 3.4 $\pm$ 5.9 mm ($p < .01$). The posterior digastric relapsed back almost totally (-7.4 $\pm$ 4.6 mm, $p < .001$), while the anterior digastric length continued to increase slightly but not significantly (+1.1 $\pm$ 3.5 mm). The posterior digastric length was increased in every patient during surgery and decreased in every patient during the follow-up period. The anterior digastric length, as measured from the hyoid bone to the inferior lingual aspect of the mandibular symphysis, was increased in 18 of the 26 patients during surgery with a maximum increase of 14.4 mm. During the follow-up period, this length increased in 16 of the patients and decreased in ten of the patients. The surgical increases ranged from +0.4 mm to 7.3 mm with most lying between 1.3 and 4.2 mm. The postoperative decreases ranged evenly from -0.2 mm to -4.8 mm. There was a weak correlation between the relapse of the posterior digastric length and the surgical change in the posterior digastric length ($r = -0.59$). But, there were no correlations between the changes for these muscle lengths and the relapse values for any linear or angular hard tissue measurement (all $r < .50$).

The anterior and posterior mylohyoid lengths were increased during surgery. Anterior mylohyoid as measured from the hyoid bone to the lingual aspect of the mandibular symphysis opposite the lower incisor apex was increased by 4.1 ± 4.9 mm ($p < .001$) and the posterior mylohyoid, as measured from the hyoid bone to the apex of the mandibular first molar, was increased by 3.7 ± 4.6 mm ($p < .001$). Both of these lengths decreased significantly postsurgically: the anterior mylohyoid by -2.1 ± 3.7 mm ($p < .01$) and the posterior mylohyoid by -5.2 ± 4.1 mm ($p < .001$), which was more than the amount it was lengthened during surgery. The anterior mylohyoid length increased in 21 of the 26 patients, with a maximum increase of 13.8 mm. It shortened postsurgically in 16 of the 26 patients with the maximum decrease of -8.4 mm. Only four patients stayed within 1 mm of their immediate postsurgical position. The posterior mylohyoid length also increased in 21 of the 26 patients with a maximum increase of 13.7 mm. It shortened during the postsurgical follow-up in all but four of the patients, showing a maximum decrease of -10.9 mm, and it remained within 1 mm of its immediate postsurgical length in only four patients. There was a weak correlation between the relapse of the anterior mylohyoid and its surgical change ($r = -0.56$), and a moderate correlation between the relapse of the posterior mylohyoid and its surgical change ($r = -0.79$). No correlation was found between changes in the lengths of these muscles and any changes in the hard tissue measurements ($r < 0.5$).

Rigid Sample - Changes in Hyoid Position and Head Posture

(Table 8: Measurements 6, 7, 8, and 9, p. 49)

During surgery the hyoid bone tended to move anteriorly (6.1 ± 5.0 mm, $p < .001$) and inferiorly (5.5

$\pm$ 4.5 mm, $p < .001$). In the postsurgical period it was very stable in a horizontal direction (0.0 $\pm$ 5.0, p: N.S.) but relapsed caudally to a greater degree than it was moved during surgery (-8.1 $\pm$ 4.6 mm, $p < .001$). In relation to the most anterior superior aspect the first cervical vertebrae, the hyoid bone also moved farther away (5.6 $\pm$ 3.2 mm, $p < .001$) and then relapsed back to almost the same distance as the original surgical movement (-5.1 $\pm$ 3.1 mm, $p < .001$).

The hyoid bone moved anteriorly in all but one patient during surgery. During the follow-up period it relapsed posteriorly in 50 percent of the patients and continued to move anteriorly in the other half. The maximum relapse was +13.0 mm. During this follow-up, the horizontal position stayed within 1 mm of its postsurgical position in only four of the patients. In most patients it moved from between 2 to 6 mm horizontally in one direction or the other. In the vertical dimension the hyoid bone moved inferiorly in all but two of the patients during surgery and superiorly in all patients during the follow-up period. The maximum surgical movement was 16.8 mm and the maximum relapse was -15.2 mm. In only two patients did it stay within 1 mm of its postsurgical position. There was no correlation between the horizontal relapse of the hyoid position and its surgical movement. There was a weak correlation between the vertical relapse of the hyoid bone and its surgical movement ($r = -0.61$). There were no correlations between changes in the hyoid bone position and the changes in any other hard tissue landmarks ($r < 0.5$).

In relation to cervical spine 1, the hyoid bone to cervical spine 1 distance increased during surgery in every patient and decreased during follow-up in every patient. The maximum increase during surgery was 13.2 mm and the maximum relapse was -12.6 mm. The relapse was moderately correlated to the surgical change ($r = -0.75$) and was also very weakly correlated to the relapse in the mandibular plane angle ($r = -0.56$).

Head posture was changed to a slightly more forward head position during surgery, as indicated by an increase in the distance from occiput to atlas (1.5 $\pm$ 2.2 mm, $p < .01$). During the follow-up period this head position remained fairly stable (occiput to atlas distance change = -0.1 ± 2.0 mm, p: N.S.). This increase in occiput to atlas distance was seen in 23 of the 26 patients with a maximum increase in distance of 10.1 mm. During follow-up 19 of the 26 remained within 1 mm of their postsurgical value. The greatest change seen was -5.8 mm. There was no correlation between the changes in the occiput to atlas distance and any other measured variable ($r < 0.5$).

Skeletal Wire Fixation

Skeletal Wire Fixation Sample - Anteroposterior Movement of the Maxilla

(Table 9: Measurements 1, 2 and 3)

Evaluating the anteroposterior change of the maxilla, there was a very small increase in the average SNA angle during surgery (+0.2 deg ± 2.5, p: N.S.) and in the forward horizontal movement of A Pt. (+0.3 mm ± 2.6, p: N.S.). Both of these measurements relapsed by a small amount which was equal to their surgical movement (SNA relapse = -0.2 deg ± 1.2, p: N.S.; A Pt. horizontal relapse = -0.3 mm ± 1.0, p: N.S.). Six of the nine patients showed less than 1 mm of relapse and

TABLE 9.--Skeletal Wire Fixation Sample - Maxillary Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change	Post-Op Change
1. SNA Angle	78.8	79.0	78.8	+0.2 N.S.	-0.2 N.S.
Std Dev (deg)	4.4	2.9	3.3	2.5	1.2
2. A Pt Hor	67.8	68.1	67.8	+0.3 N.S.	-0.3 N.S.
Std Dev (mm)	4.5	3.2	2.8	2.6	1.0
3. PNS Hor	26.6	28.3	28.4	+1.7 N.S.	+0.1 N.S.
Std Dev (mm)	2.4	3.1	3.4	3.1	1.1
4. A Pt Vert	55.6	53.4	54.2	-2.2 N.S.	+0.8 N.S.
Std Dev (mm)	6.2	6.2	6.0	3.1	1.8
5. PNS Vert	45.6	45.1	45.5	-0.5 N.S.	+0.4 N.S.
Std Dev (mm)	3.5	3.2	3.1	2.2	0.9

+ = anterior or inferior
- = posterior or inferior

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

there was no change during the follow-up period greater than 2 mm. There was no correlation between the amount of surgical movement and the amount of relapse seen.

A larger anterior horizontal movement was found when evaluating the posterior maxilla (+1.7 $\pm$ 3.1 mm, p: N.S.). This was due to the fact that in two of the patients with three piece maxillary procedures extraction spaces were closed during surgery. The posterior maxilla was stable during the follow-up period, showing a slight forward movement of only +0.1 $\pm$ 1.1 mm (p: N.S.).

<u>Skeletal Wire Fixation Sample - Vertical Movement of the Maxilla</u>

(Table 9: Measurements 4 and 5, p. 56)

The anterior maxilla was impacted more than the posterior maxilla (-2.2 $\pm$ 3.1 mm, p: N.S. versus -0.5 $\pm$ 2.2 mm, p: N.S.) and both tended to relapse inferiorly during the follow-up period. The anterior maxilla relapsed +0.8 $\pm$ 1.8 mm inferiorly (p: N.S.) while the posterior maxilla relapsed inferiorly by +0.4 $\pm$ 0.9 mm (p: N.S.). The anterior segment of the maxilla stayed within 1 mm of its postsurgical position during the follow-up period in five of the nine patients. The posterior segment was more stable, staying within 1 mm of its postsurgical value in eight of the nine patients. The anterior segment relapsed more than 1 mm inferiorly in three of the nine patients with a maximum relapse of +4.7 mm. Posteriorly, the one patient with relapse of more than 1 mm, relapsed inferiorly 2.3 mm.

There was a very weak correlation between the vertical relapse of the anterior maxilla and the amount of surgical impaction ($r = -0.55$). This correlation was weaker for the posterior maxilla ($r = -0.44$) but the relapse of the posterior maxilla did show a very weak correlation to the relapse of the posterior facial height ($r = +0.50$).

<u>Skeletal Wire Fixation Sample - Movement of the Mandible as measured from B Pt.</u>

(Table 10: Measurements 1, 2, 3 and 4)

The average mandibular advancement in the horizontal direction was $+7.1 \pm 3.9$ mm ($p < .001$) with advancements ranging from 1.7 to 11.8 mm. This resulted

TABLE 10.--Skeletal Wire Fixation Sample - Mandibular Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. SNB Angle	72.1	76.2	75.1	+4.1	**	-1.1	*
Std Dev (deg)	3.7	4.9	4.3	2.4		1.4	
2. ANB Angle	6.8	2.8	3.7	-4.0	**	+0.9	N.S.
Std Dev (deg)	2.9	3.5	3.0	3.6		1.4	
3. B Pt Hor	52.4	59.5	57.6	+7.1	***	-1.9	*
Std Dev (mm)	5.6	8.1	6.8	3.9		2.4	
4. B Pt Vert	95.1	94.7	94.3	-0.4	N.S.	-0.4	N.S.
Std Dev (mm)	7.8	7.5	7.3	3.1		2.1	
5. Body Length	65.6	70.3	68.2	+4.7	*	-2.0	N.S.
Std Dev (mm)	3.4	5.6	6.0	4.2		3.1	
(Go to Me)							
6. Total Length	106.6	112.6	110.3	+6.0	**	-2.3	*
Std Dev (mm)	3.9	5.4	4.8	4.4		2.3	
(Ar to Me)							
7. Prox Seg Ln	51.4	51.8	49.8	+0.4	N.S.	-2.0	*
Std Dev (mm)	5.1	5.9	6.1	1.6		2.2	
(Ar to Go)							

+ = anterior or inferior
- = posterior or inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

in a +4.1 ± 2.4 degree increase in the SNB angle ($p < .01$) and a -4.0 ± 3.6 degree reduction in the ANB angle ($p < .01$). The horizontal projection of B Pt. relapsed -1.9 ± 2.4 mm ($p < .05$) during the follow-up period with a -1.1 ± 1.4 degree ($p < .05$) relapse in the SNB angle and a +0.9 ± 1.4 degree (p: N.S.) relapse in the ANB angle. Four of the nine patients remained within 1 mm of their postsurgical horizontal position but the other five patients relapsed -1.5 mm, -1.9 mm, -3.0 mm, -3.6 mm and -6.9 mm.

The relapse of B Pt. in the horizontal position showed a moderate correlation to its surgical advancement ($r = -0.69$) and to the relapse of mandibular total length ($r = +0.74$). It also showed very weak correlations to the relapse of the posterior digastric length ($r = 0.56$), the relapse in the anterior digastric length ($r = +0.55$), and the relapse in the vertical position of the hyoid bone ($r = -0.58$). The relapse in SNB angle showed a strong correlation ($r = +0.97$) to the relapse in the horizontal position of B Pt. The relapse in ANB angle showed a very weak correlation to both the relapse of B Pt. in the horizontal direction ($r = -0.53$)

and to the relapse of A Pt. in the horizontal direction ($r = +0.57$). The relapse in ANB showed a weak correlation to the relapse in posterior digastric length ($r = +0.61$) and the relapse in posterior mylohyoid length ($r = +0.64$), and a moderate correlation to the vertical relapse of the hyoid bone ($r = +0.73$).

The average vertical changes in the mandible as measured at B Pt. were quite small during surgery (-0.4 ± 3.1 mm, p: N.S.) and during the follow-up period (-0.4 ± 2.1 mm, p: N.S.). B Pt. continued to move superiorly in six of the nine patients with a range of superior movement of -0.2 mm to -2.8 mm. In the other three patients B Pt. moved inferiorly up to +3.5 mm. There was a weak correlation between the relapse in the vertical position of B Pt. and the relapse in the posterior facial height ($r = +0.68$).

Skeletal Wire Fixation Sample - Changes in Mandibular Length

(Table 10: Measurements 5, 6 and 7, p. 59)

Evaluating the surgical changes by utilizing measurements within the mandible showed a significant increase in both the total mandibular length as measured from articulare to menton (+6.0 $\pm$ 4.4 mm, $p < .01$) and the mandibular body length, as measured from gonion to menton, (+4.7 $\pm$ 4.2 mm, $p < .05$). The total length relapsed -2.3 $\pm$ 2.3 mm ($p < .05$) and the body length relapsed -2.0 $\pm$ 3.1 mm (p: N.S.). The total length stayed within 1 mm of its postsurgical value in only four of the nine patients with the remainder showing relapses of from -1.6 mm to -6.0 mm. The body length showed a similar distribution with only three of the nine patients remaining within 1 mm of their postsurgical values. The relapse in body length was up to -9.1 mm, with four patients showing relapse between 2 mm and 4 mm. There was no correlation between the amount of surgical advancement and the amount of relapse for either of these variables ($r = -0.41$ for total length and $r = -0.05$ for body length). There was a weak correlation between the relapse in the total length and the relapse in the body length ($r = +0.67$). The relapse in total length showed a weak correlation to the relapse in the gonial angle ($r = -0.63$). The relapse in mandibular body length showed a stronger correlation to the relapse in the gonial angle (r = -0.82) as well as to the relapse in the proximal segment angle (r =+0.74).

As with the rigid sample, the skeletal wire sample was divided into those patients with less than 5 mm of mandibular advancement (N =4) and those with 5 mm or more of advancement (N = 5) based upon the measurement of mandibular body length. No patients had advancements greater than 10 mm. The subset of patients with greater than 5 mm of advancement was less stable in terms of the mandibular body length (-2.5 mm versus -1.5), the mandibular total length (-2.9 mm versus -1.6) and the horizontal projection of B Pt. (-2.5 mm versus -1.0 mm). No statistical analysis was performed due to the small number of patients in each subset.

The data showed that the proximal segment length as measured from articulare to gonion was increased slightly during surgery (+0.4 $\pm$ 1.6 mm, p: N.S.) and then decreased significantly during the follow-up period (-2.0 $\pm$ 2.2 mm, $p < .05$). The immediate postsurgical proximal segment length was within 1 mm of its presurgical length in five of the nine patients and in three of the patients it was increased postsurgically from 1.5 to 2.7 mm. The proximal segment length decreased in every patient during the follow-up period, with five of the nine patients staying within 1 mm of their presurgical value. In the other four patients, decreases in length of from -2.5 to -6.2 mm were seen. There was no correlation between the amount of relapse in proximal segment length and the amount of surgical change ($r < 0.5$). There was a strong correlation between the decrease in the proximal segment length and the relapse in posterior facial height ($r = +0.89$).

Skeletal Wire Fixation Sample - Changes in Mandibular Angular Measurements

(Table 11: Measurements 4, 5 and 6)

The three angular measurements within the mandible relate to the rotational changes within the mandible (gonial angle) and to its relation to the cranial base (mandibular plane angle and the proximal segment angle). During surgery there were decreases in both the proximal segment angle, as measured by the angle formed by the SN line with the line from articulare to gonion, (-4.2 ± 3.0 deg., $p < .01$) and in

TABLE 11.--Skeletal Wire Fixation Sample - Angular Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. SNA Angle	78.8	79.0	78.8	+0.2	N.S.	-0.2	N.S.
Std Dev (deg)	4.4	2.9	3.3	2.5		1.2	
2. SNB Angle	72.1	76.2	75.1	+4.1	**	-1.1	*
Std Dev (deg)	3.7	4.9	4.3	2.4		1.4	
3. ANB Angle	6.8	2.8	3.7	-4.0	**	+0.9	N.S.
Std Dev (deg)	2.9	3.5	3.0	3.6			1.4
4. Man Plane to SN	38.2	37.2	39.2	-1.0	N.S.	+2.0	N.S.
Std Dev (deg)	7.2	7.8	8.2	3.2		2.9	
5. Prox Seg to SN	88.2	84.1	82.6	-4.2	**	-1.5	N.S.
Std Dev (deg)	4.1	3.9	4.8	3.0		2.2	
6. Goniol Angle	130.7	133.7	137.9	+3.0	N.S.	+4.2	**
Std Dev (deg)	4.1	5.0	6.1	4.0		3.3	
7. Upper 1 to SN	102.7	103.3	102.3	+0.6	N.S.	-1.0	N.S.
Std Dev (deg)	7.3	6.6	6.3	7.4		2.9	
8. Lower 1 to MP	89.8	91.2	90.4	+1.3	N.S.	-0.8	N.S.
Std Dev (deg)	7.3	7.7	6.3	2.2		3.0	

+ = anterior or inferior
- = posterior or inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

the mandibular plane angle (-1.0 ± 3.2 deg., p: N.S.) indicating an autorotation of the mandible. At the same time the gonial angle increased ($+3.0 \pm 4.0$ deg., p: N.S.) indicating a clockwise rotation pattern within the mandible itself. During the follow-up period the proximal segment angle continued to decrease a small amount (-1.5 ± 2.2 deg., p: N.S.). However, due to a large increase in the gonial angle during this time ($+4.2 \pm 3.3$ deg., $p < .01$) the mandibular plane angle relapsed slightly ($+2.0 \pm 2.9$ deg., p: N.S.). The proximal segment angle was decreased in every patient during surgery indicating an autorotation movement. However, since every patient but one also showed a counterclockwise rotation within the mandible during surgery (as indicated by an increase in the gonial angle), the mandibular plane angle only decreased in five of the nine patients.

There was no correlation between the amount of surgical movement and the amount of relapse for the mandibular plane angle ($r = +0.02$) or for the proximal segment angle ($r = +0.32$). There was a weak positive correlation between surgical change and relapse of the gonial angle (r = +0.69). A weak correlation was found between the relapse in the mandibular plane angle and the relapse in the mandibular total length (r = -0.66). The relapse in mandibular plane angle also showed a moderate correlation to the relapse in some muscle lengths (posterior digastric, r = 0.79 and posterior mylohyoid, r = 0.79). The relapse in the gonial angle also showed a weak correlation to the relapse in mandibular total length (r = -0.63) and to the relapse in the posterior mylohyoid length (r = 0.61). The relapse in the proximal segment angle showed no such correlations.

Skeletal Wire Fixation Sample - Changes in Incisor Angulation

(Table 11: Measurements 7 and 8, p.65)

The angulation of the upper incisor to SN started with a mean value of 102.7 and this was increased slightly during surgery (+0.6 ± 7.4 deg., p: N.S.). During the follow-up period, the upper incisor angulation decreased slightly (-1.0 ± 2.9 deg., p: N.S.). The surgical change in angulation of the upper incisor was extremely variable, ranging from -8.0 degrees to +16.5 degrees and the follow-up changes varied from -5.5 degrees to +4.0 degrees. There were no correlations with any other relapse measurements.

The angulation of the lower incisor to the mandibular plane increased slightly during surgery (+1.3 $\pm$ 2.2 deg., P= N.S.) and then decreased during the follow-up period (-0.8 $\pm$ 3.0 deg., p: N.S.). The changes during surgery varied from -1.5 to +4.0 degrees and during the follow-up from -6.0 to +3.0 degrees. There were no correlations between the relapse values and any other measurements ($r < 0.5$).

<u>Skeletal Wire Fixation Sample - Changes in Muscle Length Measurements</u>

(Table 12: Measurements 1, 2, 3, 4 and 5)

The mean posterior facial height (as measured from sella to gonion) was decreased during surgery by -1.1 $\pm$ 1.2 mm ($p < .05$) and this value continued to decrease during the follow-up period by an additional -2.1 $\pm$ 1.7 mm ($p < .05$). Posterior facial height was

TABLE 12.--Skeletal Wire Fixation Sample - Muscle Lengths, Hyoid Bone Position and Head Posture - Surgical Changes and Postoperative Relapse

Variable	T1	T2	T3	Surgical Change		Post-Op Change	
1. Post Fac Ht	84.3	83.2	81.1	-1.1	*	-2.1	*
Std Dev (mm)	8.0	7.9	8.0	1.2		1.7	
2. Post Digastic	89.2	95.3	91.7	+6.2	***	-3.6	*
Std Dev (mm)	6.6	5.1	6.9	3.5		3.4	
3. Ant Digastric	39.8	44.2	41.5	+4.4	N.S.	-2.7	N.S.
Std Dev (mm)	6.9	5.9	4.7	6.2		4.2	
4. Post Mylohyoid	27.0	32.6	28.2	5.5	**	-4.3	*
Std Dev (mm)	4.2	4.0	5.7	3.6		5.6	
5. Ant Mylohyoid	47.3	52.3	47.9	+4.9	*	-4.4	*
Std Dev (mm)	8.1	6.4	6.2	5.6		4.5	
6. Hyoid Horizontal	1.0	4.2	5.7	+3.3	N.S.	+1.5	N.S.
Std Dev (mm)	5.5	7.5	5.6	4.7		4.3	
7. Hyoid Vertical	108.4	113.3	108.8	+4.9	**	-4.7	*
Std Dev (mm)	8.5	6.9	9.6	4.3		4.7	
8. C1 to Hyoid	35.3	40.9	36.8	+5.6	***	-4.1	**
Std Dev (mm)	5.3	6.0	5.6	2.8		2.5	
9. Occ to Atlas	5.7	5.6	7.2	-0.1	N.S.	+1.6	**
Std Dev (mm)	2.5	2.4	2.1	1.1		1.3	

+ = anterior or inferior
- = posterior or inferior

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

increased during the surgical period in only one patient. It remained unchanged in two patients and was decreased by up to -2.6 mm in the other six patients. During the follow-up period, it increased in three patients and decreased in the other six (range = -6.5 mm to +1.9 mm). The relapse in posterior facial height showed a moderate correlation to the relapse in the vertical position of the hyoid bone ($r = -0.72$) and a strong correlation to the relapse in proximal segment length ($r = +0.89$).

The digastric muscle lengths were both increased during surgery. The posterior digastric (as measured from a point on the mastoid process to the hyoid bone) was increased by $+6.2 \pm 3.5$ mm ($p < .001$) and the anterior digastric (as measured from the hyoid bone to a point on the inferior lingual aspect of the mandibular symphysis) was increased by $+4.4 \pm 2.2$ (p: N.S.). The posterior digastric relapsed back over 50% of the surgical change (-3.6 ± 3.4 mm, $p < .05$) as did the anterior digastric (-2.7 ± 4.2 mm, p: N.S.). The posterior digastric length increased in all but one patient during surgery and decreased in all but one patient during the follow-up period. The anterior digastric length was more variable, increasing in six patients during surgery (range = -4.0 to +13.6 mm) and decreasing in six patients during the follow-up period (range = -7.0 to +5.1 mm). There were weak correlations between the surgical increase and the relapse values for the posterior digastric length ($r = -0.51$) and the anterior digastric length ($r = -0.66$). There was also a moderate correlation between the relapse of the posterior digastric length and the relapse in the mandibular plane angle ($r = +0.79$). The relapse in the anterior digastric length did not correlate with any other linear or angular measurements.

The anterior and posterior mylohyoid lengths were also increased during surgery and decreased during the follow-up period. The posterior mylohyoid, as measured from the hyoid bone to the apex of the first molar roots, increased +5.5 $\pm$ 3.6 mm ($p < .01$) during surgery and then relapsed almost the same amount during the follow-up period (-4.3 $\pm$ 5.6 mm, $p < .05$). The anterior mylohyoid ,as measured from the hyoid bone to lingual aspect of the mandibular symphysis opposite the incisor root, increased in length +4.9 $\pm$ 5.6 mm ($p < .05$) and it also relapsed almost the total amount during the follow-up period (-4.4 $\pm$ 4.5 mm, $p < .05$). The posterior mylohyoid length was increased surgically in every patient (range = +1.0 to +12.9 mm) and decreased in all but two patients during the follow-up period (range = -13.7 to +3.4 mm). The anterior mylohyoid was more increased during surgery in seven of the nine patients (range = -3.3 to +12.9 mm) and decreased in seven of the nine patients during the follow-up period (range = -11.1 to +2.1 mm). There were moderate correlations between the amount of relapse and the amount of surgical increase in length change for both the posterior mylohyoid ($r = -0.77$) and the anterior mylohyoid ($r = -0.78$). There was also a moderate correlation between the amount of relapse in the posterior mylohyoid and the relapse of the mandibular plane angle ($r = +0.79$). The relapse of the anterior mylohyoid did not correlate with the relapse of any other measurements ($r < 0.5$).

Skeletal Wire Sample - Changes in Hyoid Position and Head Posture

(Table 12: Measurements 6, 7, 8 and 9, p.69)

The hyoid bone tended to move anteriorly (+3.3 $\pm$ 4.7 mm, p: N.S.) and inferiorly (+4.9 $\pm$ 4.3 mm, $p < .01$) during the surgical period. Postsurgically it tended to move slightly more anteriorly (+1.5 $\pm$ 4.3 mm, p: N.S.) and to relapse superiorly back close to its original position (-4.7 $\pm$ 4.7 mm, $p < .05$). In relation to the first cervical vertebrae the hyoid bone moved anteriorly during surgery (+5.6 $\pm$ 2.8 mm, $p < .001$) and then relapsed back during the follow-up period (-4.1 $\pm$ 2.5 mm, $p < .01$).

During surgery the hyoid bone moved anteriorly in seven of nine patients (range = -4.0 mm to +11.8 mm). The movements were split evenly during the follow-up period with anterior movement in five patients and posterior movement in four (range = -3.7 mm to +9.8 mm).

In the vertical dimension, the hyoid bone moved inferiorly during surgery in all but one patient (range = -1.3 mm to +11.9 mm) and then superiorly in all but that one patient during follow-up (range = -11.4 to

0.0 mm). The distance form the hyoid bone to the cervical vertebrae increased in all but one patient during surgery (range = -0.4 to +8.2 mm) and decreased during follow-up in all but one patient (range = -6.3 to +0.6 mm). In only one or two patients did the values for any of these variables stay within 1 mm of its postsurgical value. The relapse of the hyoid bone in the horizontal dimension did not correlate with its surgical movement or with any other variable. The relapse of the hyoid bone in the vertical dimension did have a moderate correlation with its surgical movement ($r = -0.78$) and strong correlations with the relapse values for the posterior digastric ($r = +0.89$) and the posterior mylohyoid ($r = +0.82$). The relapse of the hyoid to the cervical vertebrae had a weak correlation to the amount of surgical change ($r = -0.67$) but not to any other variable ($r < 0.5$).

The head posture stayed essentially the same during surgery as measured by the distance from occiput to atlas (-0.1 ± 1.1 mm, p: N.S.) and then moved to a slightly more head down posture during the follow-up period ($+1.6 \pm 1.3$ mm, $p < .01$). The surgical change was variable from patient to patient (range = -1.1 to +2.2 mm) with a decrease in the distance in five patients and an increase in four. During the follow-up period the distance increased in seven of the nine patients (range = -0.9 mm to +2.8 mm). The relapse value showed only a very weak correlation to the relapse in anterior digastric length (r = -0.57). No other correlations with head posture were noted.

Rigid Fixation Versus Skeletal Wire Fixation

Rigid Fixation Versus Skeletal Wire Fixation - Anteroposterior Movement of the Maxilla

(Table 13: Measurement 1, 2 and 3; Figure 2)

The anterior maxilla was advanced more in the rigid fixation sample than in the skeletal wire fixation sample both when evaluated from the SNA measurement (+1.4 deg. versus +0.2 deg., p: N.S.) and from the horizontal advancement of A Pt. (+1.9 mm versus +0.3 mm, p: N.S.). The resulting position tended to be more stable on average for the rigid fixation sample (SNA relapse: 0.0 deg., A Pt. Hor. relapse: 0.0 mm) than for the skeletal wire fixation sample (SNA relapse: -0.2

TABLE 13.--Rigid Fixation Versus Skeletal Wire Fixation - Maxillary Surgical Changes and Postoperative Relapse Comparison

Variable	Surgical Changes Rigid	Skeletal	Sig	Post-Op Changes Rigid	Skeletal	Sig
1. SNA Angle (deg)	+1.4	+0.2	N.S.	0.0	-0.2	N.S.
2. A Pt. Hor. (mm)	+1.9	+0.3	N.S.	0.0	-0.3	N.S.
3. PNS Hor. (mm)	+1.7	+1.7	N.S.	+0.4	+0.1	N.S.
4. A Pt. Vert. (mm)	-2.5	-2.2	N.S.	+0.1	+0.8	N.S.
5. PNS Vert. (mm)	-0.6	-0.5	N.S.	-0.2	+0.4	N.S.

+ = anterior or inferior
- = posterior or inferior

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

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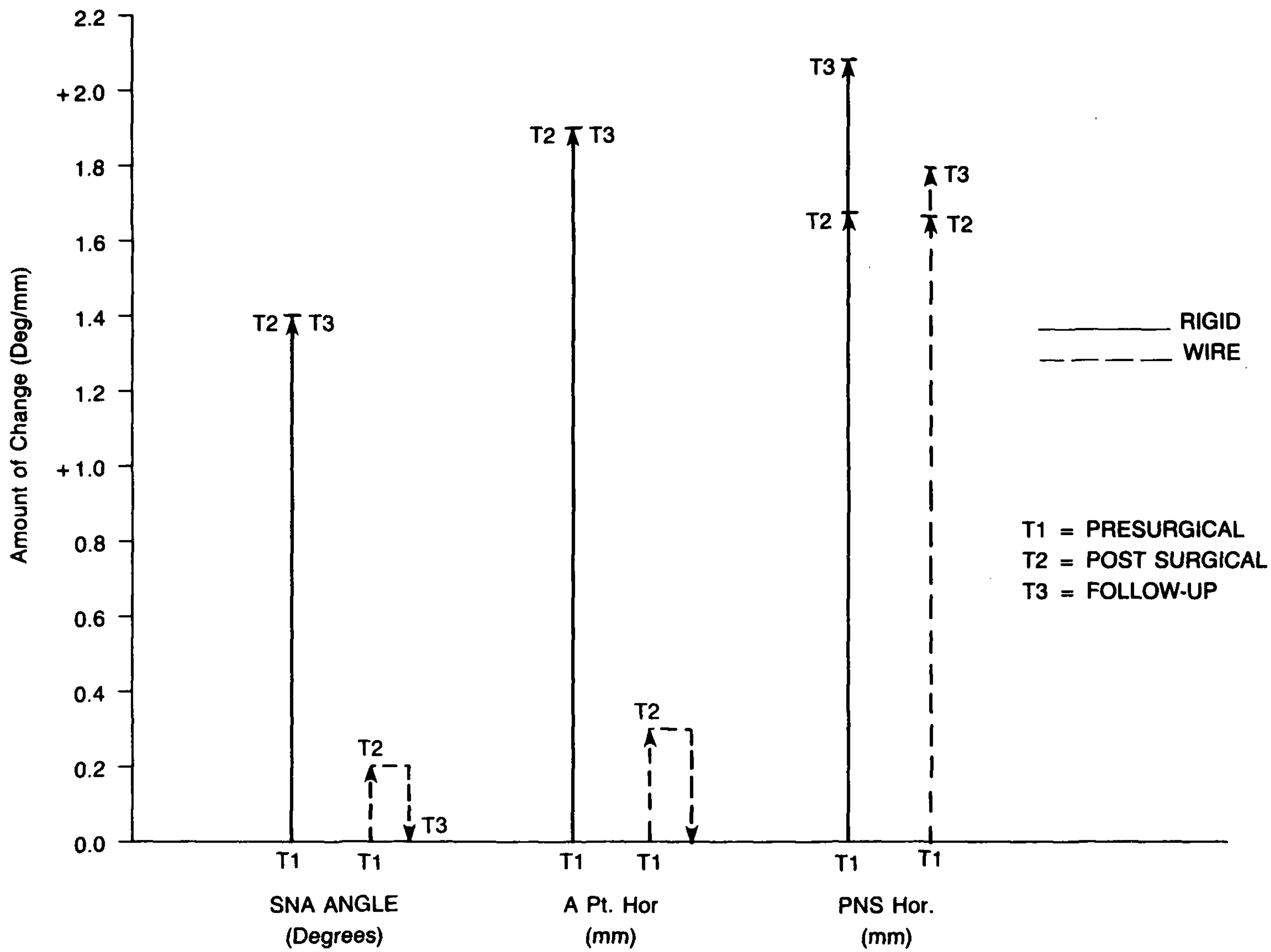
FIGURE 2.--Maxillary AP Surgical Changes and Relapse



Amount of Change (Deg/mm)
2.2
+2.0
1.8
1.6
1.4
1.2
+1.0
0.8
0.6
0.4
0.2
0.0
T1
T2
T3
SNA ANGLE
(Degrees)
A Pt. Hor
(mm)
PNS Hor.
(mm)
RIGID
WIRE
T1 = PRESURGICAL
T2 = POST SURGICAL
T3 = FOLLOW-UP

deg., A Pt. Hor. relapse: -0.3 mm) although the differences were not statistically significant. With both techniques about two-thirds of the patients stayed within 1 mm of their postsurgical position (rigid: 18/26, skeletal wire: 6/9) but those that relapsed in the skeletal wire sample had a greater tendency to relapse posteriorly.

The surgical advancement of the posterior maxilla was comparable in both samples (rigid: +1.7 mm, skeletal wire : +1.7 mm, p: N.S.). Postsurgically, the rigid sample tended to move anteriorly more than the skeletal wire sample (rigid: +0.4 mm, skeletal wire: +0.1 mm, p: N.S.) and, again, the difference was not statistically significant. A greater proportion of patients in the rigid sample stayed within 1 mm of their postsurgical position (rigid: 21/25, skeletal wire: 5/9). However, the trend for the rigid sample was further anterior movement, whereas the skeletal wire sample showed about equal numbers moving posteriorly as moving anteriorly.

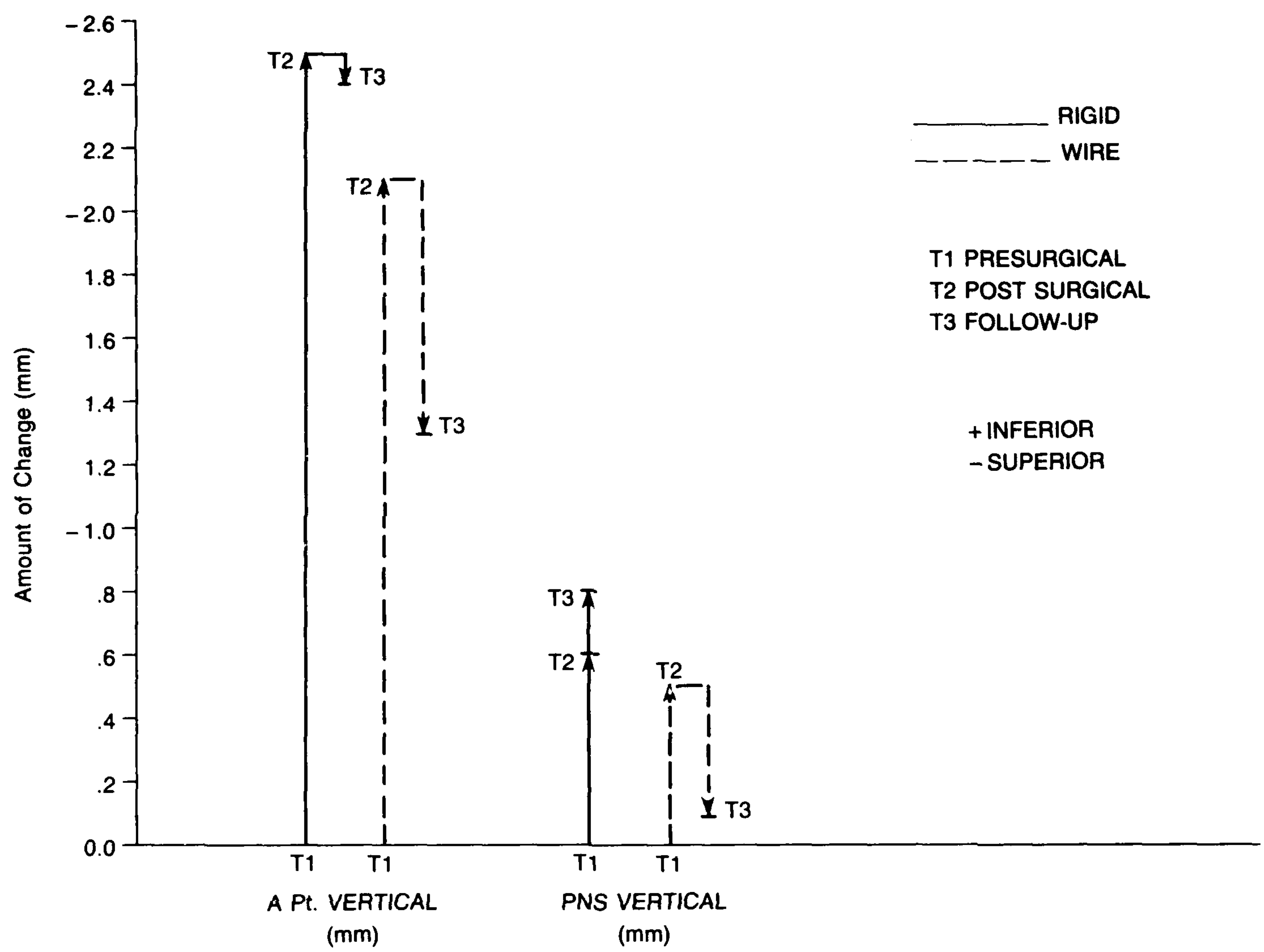
Rigid Fixation Versus Skeletal Wire Fixation - Vertical Movement of the Maxilla

(Table 13: Measurements 4 and 5, p. 76; Figure 3)

The average amount of impaction of the anterior maxilla was comparable for both samples (rigid: -2.5 mm, skeletal wire: -2.2 mm, p: N.S.) as measured at A Pt. The rigid sample tended to be more stable with a superior relapse of only +0.1 mm compared to +0.8 mm for the skeletal wire sample. The difference was not statistically significant. A higher proportion of the rigid sample stayed within 1 mm of its postsurgical position (rigid: 18/26, skeletal wire: 5/9) and the range of relapse was less for the rigid sample than for the skeletal wire sample (rigid: -2.1 to +1.9 mm, skeletal wire: -1.1 to +4.7 mm).

The posterior maxilla showed similar results with a comparable surgical impaction for each sample (rigid: -0.6 mm, skeletal wire: -0.5 mm, p: N.S.) The skeletal wire sample showing a stronger tendency to relapse inferiorly during the follow-up period (rigid: -0.2 mm, skeletal wire: +0.4 mm, p: N.S.) although the difference was not statistically significant. In both

FIGURE 3.--Maxillary Vertical Surgical Changes and Relapse



–2.6
2.4
2.2
–2.0
1.8
1.6
1.4
1.2
–1.0
.8
.6
.4
.2
0.0
Amount of Change (mm)
T1
T2
T3
T1
T2
T3
T1
T2
T3
T1
T2
T3
A Pt. VERTICAL (mm)
PNS VERTICAL (mm)
RIGID
WIRE
T1 PRESURGICAL
T2 POST SURGICAL
T3 FOLLOW-UP
+ INFERIOR
– SUPERIOR

samples the vast majority of patients stayed within 1 mm of their postsurgical position (rigid: 21/25, skeletal wire: 8/9) and the range of relapse was comparable (rigid: -2.1 to +1.0 mm, skeletal wire: -0.4 to +2.3 mm).

Rigid Fixation Versus Skeletal Wire Fixation - Movement of the Mandibles as Measured from B Pt.

(Table 14: Measurements 1, 2, 3 and 4; Figure 4)

The surgical advancement of the mandible was comparable for the two samples when evaluated by the SNB angle change (rigid: +4.7 deg., skeletal wire: +4.1 deg., p: N.S.), by the ANB angle change (rigid: -3.3 deg., skeletal wire: -4.0 deg., p: N.S.) and by the horizontal movement of B Pt. (rigid: +8.6 mm, skeletal wire: +7.1 mm, p: N.S.). During the follow-up period, the rigid fixation sample was more stable for all three variables. The difference in the relapse in SNB seen for the two samples was statistically significant (rigid: -0.4 deg., skeletal wire: -1.1 deg., $p < .05$). The relapse differences for ANB (rigid:

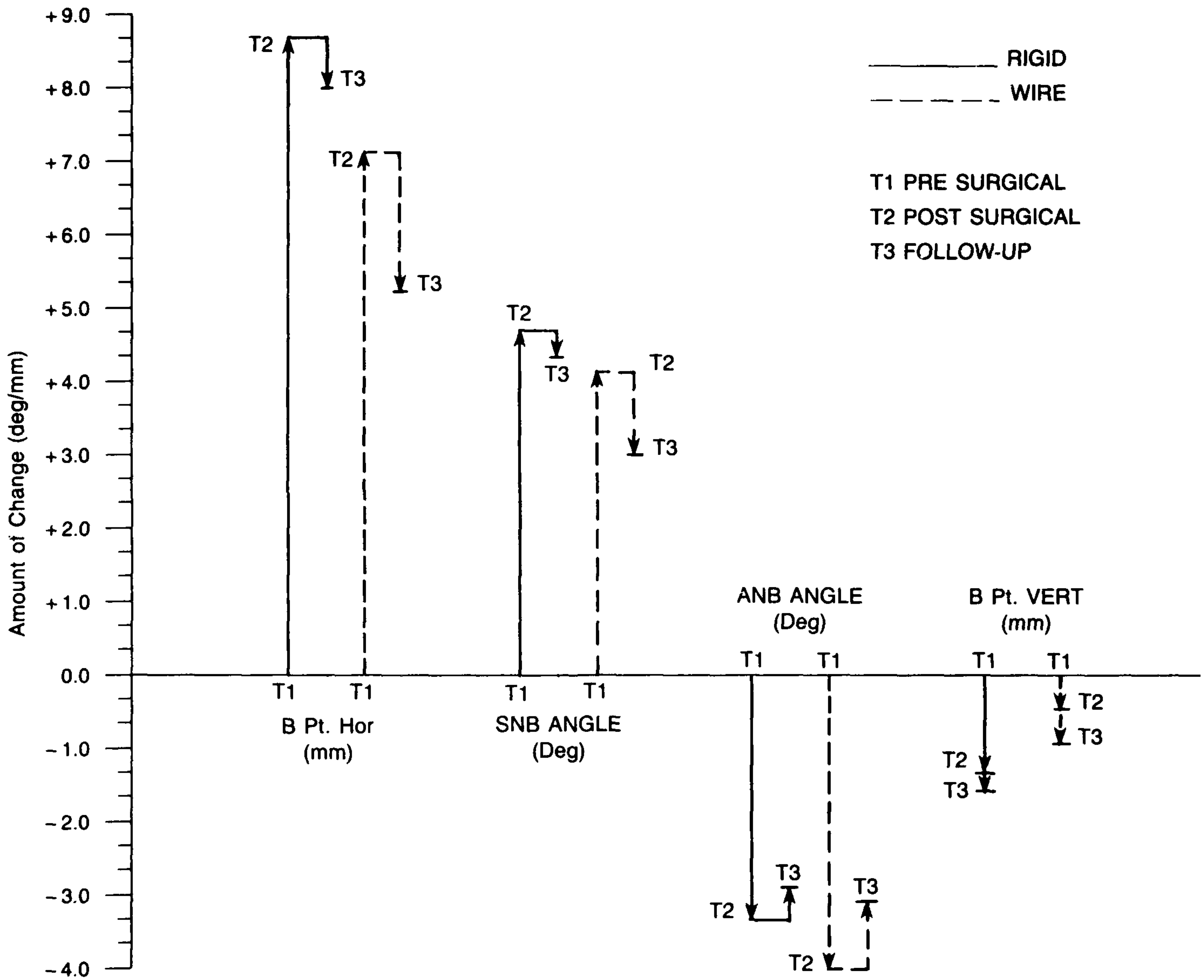
TABLE 14.--Rigid Fixation Versus Skeletal Wire Fixation - Mandibular Surgical Changes and Postoperative Relapse Comparison

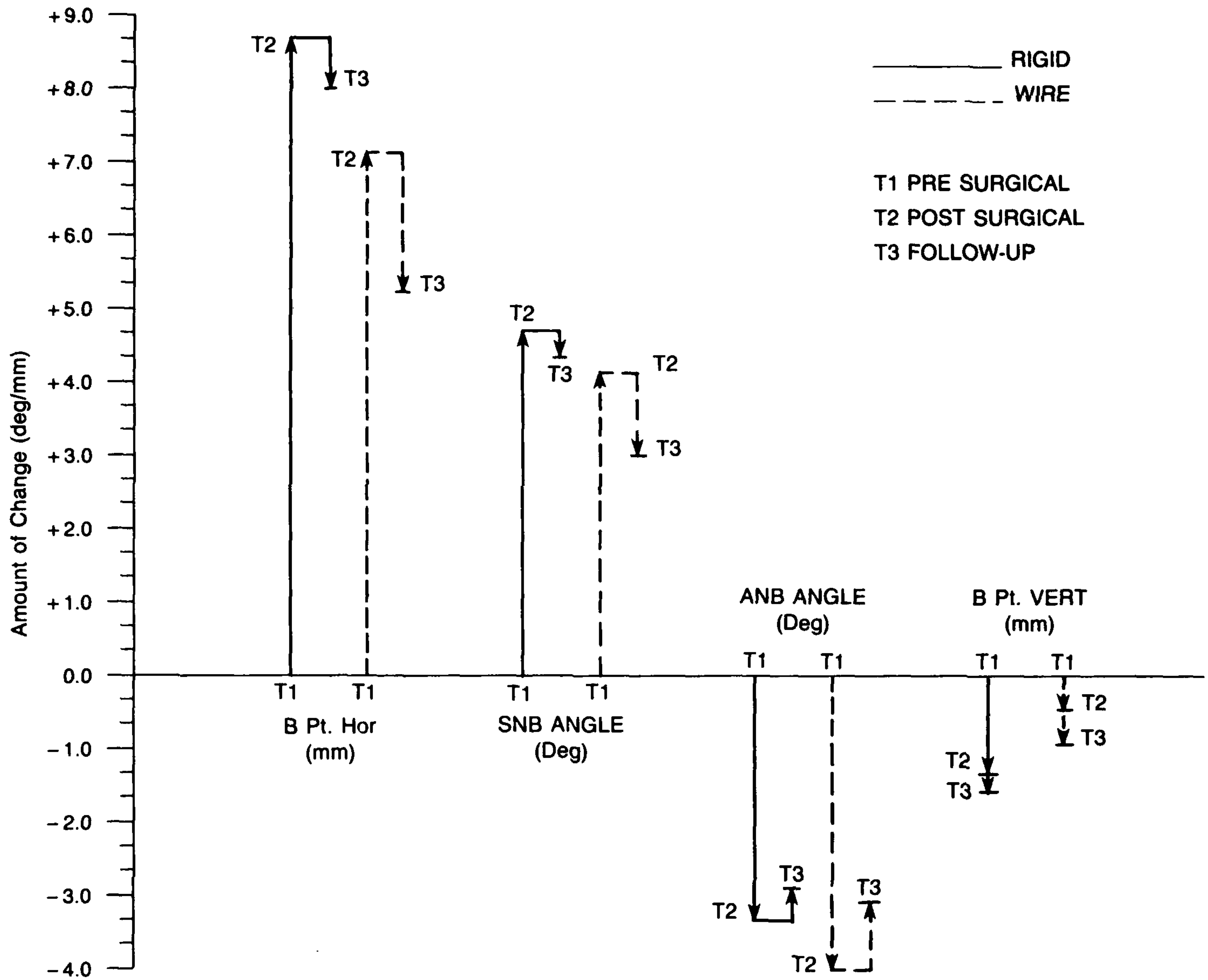
	Surgical Changes			Post-Op Changes		
Variable	Rigid	Skeletal	Sig	Rigid	Skeletal	Sig
1. SNB Angle (deg)	+4.7	+4.1	N.S.	-0.4	-1.1	*
2. ANB Angle (deg)	-3.3	-4.0	N.S.	+0.4	+0.9	N.S.
3. B Pt. Hor. (mm)	+8.6	+7.1	N.S.	-0.5	-1.9	N.S.
4. B Pt. Vert. (mm)	-1.3	-0.4	N.S.	-0.2	-0.4	N.S.
5. Body Length (mm)	+6.4	+4.7	N.S.	-0.6	-2.0	*
6. Total Length (mm)	+5.8	+6.0	N.S.	-0.7	-2.3	*
7. Prox Seg Ln (mm)	+0.2	+0.4	N.S.	-1.0	-2.0	N.S.

+ = anterior, inferior increase in value
- = posterior, inferior decrease in value

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

FIGURE 4.--Mandibular B Pt. Surgical Changes and Relapse


Amount of Change (deg/mm)
+9.0
+8.0
+7.0
+6.0
+5.0
+4.0
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
-4.0
RIGID
WIRE
T1 PRE SURGICAL
T2 POST SURGICAL
T3 FOLLOW-UP
B Pt. Hor
(mm)
SNB ANGLE
(Deg)
ANB ANGLE
(Deg)
B Pt. VERT
(mm)
T1
T2
T3



+9.0
+8.0
+7.0
+6.0
+5.0
+4.0
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
-4.0
Amount of Change (deg/mm)
RIGID
WIRE
T1 PRE SURGICAL
T2 POST SURGICAL
T3 FOLLOW-UP
B Pt. Hor
(mm)
SNB ANGLE
(Deg)
ANB ANGLE
(Deg)
B Pt. VERT
(mm)
T1
T2
T3

+0.4 deg., skeletal wire: +0.9 deg., p: N.S.) and the horizontal relapse at B Pt. (rigid: -0.5 mm, skeletal wire: -1.9 mm, p: N.S.) were not statistically significant although the t values were close to the critical t value for $P < .05$.

In both samples, about half the patients maintained their horizontal position of B Pt. within 1 mm of their postsurgical value (rigid: 13/26, skeletal wire: 4/9) but the range of relapse was greater for the skeletal wire sample (rigid: -3.5 to +2.6 mm, skeletal wire: -6.9 to +0.9 mm) and the skeletal wire sample had a greater proportion with posterior relapses greater than 2 mm (rigid: 4/26, skeletal wire: 3/9).

The surgical vertical movement of B Pt. was small for both samples (rigid: -1.3 mm, skeletal wire: -0.4 mm, p: N.S.) and so were the follow-up changes (rigid: -0.2 mm, skeletal wire: -0.4 mm, p: N.S.). The proportions of each sample staying within 1 mm of the postsurgical position were comparable (rigid: 13/26, skeletal wire: 5/9) and the range of relapse was comparable (rigid: -3.4 to +3.2 mm, skeletal wire: -2.8 to +3.5 mm).

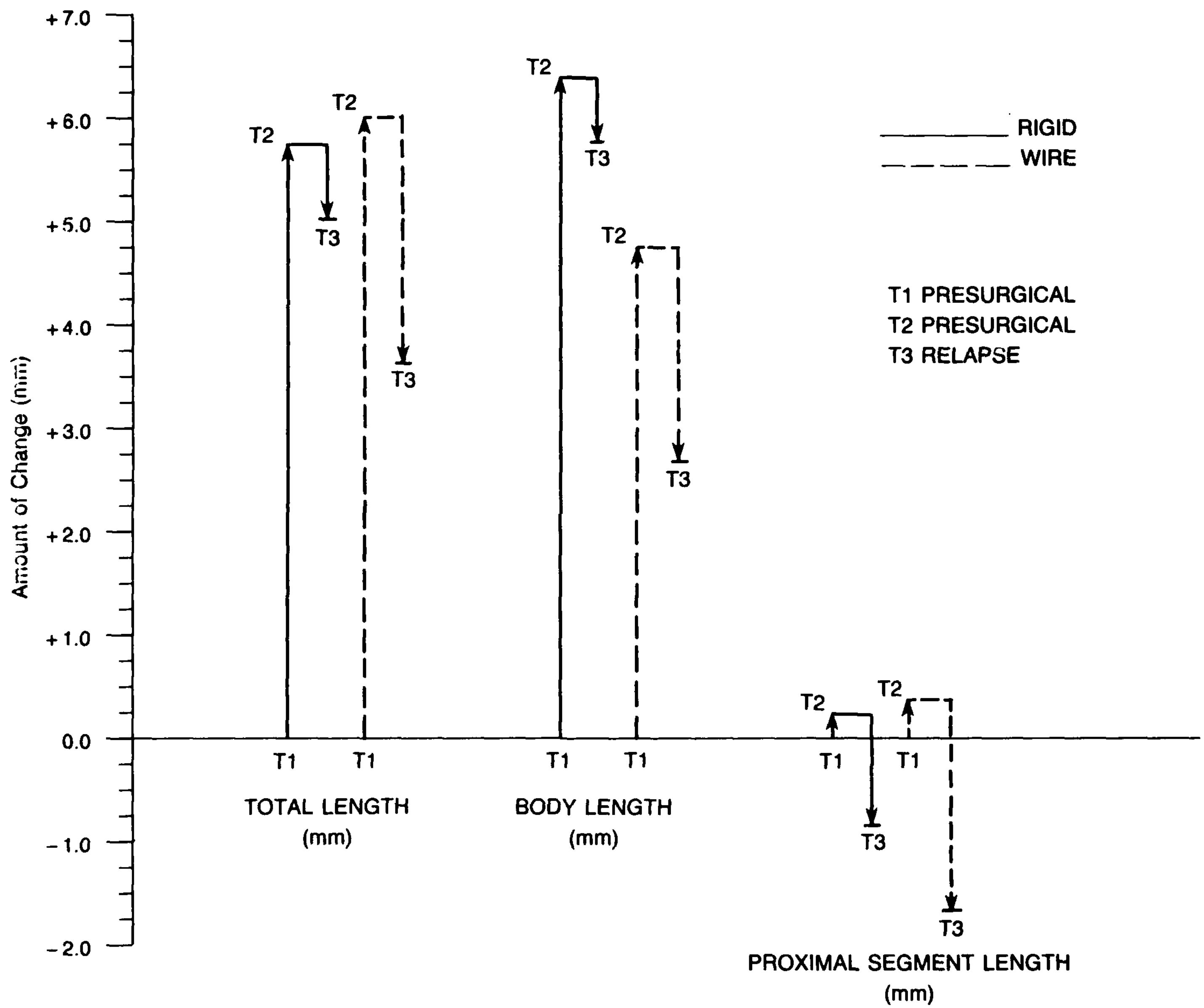
Rigid Sample Versus Skeletal Wire Sample - Changes in Mandibular Length

(Table 14: Measurements 5, 6, and 7, p. 84; Figure 5)

The surgical increase in the total length of the mandible was comparable for the two samples (rigid: +5.8 mm, skeletal wire: +6.0 mm, p: N.S.) but the body length, as measured from gonion to menton, was increased to a greater degree in the rigid sample (rigid : +6.4 mm, skeletal wire: +4.7 mm, p: N.S.). This was because the skeletal sample achieved part of its increase in total length by an increase the gonial angle with a clockwise rotation of the distal segment with respect to the proximal segment. The rigid sample was much more stable during the follow-up period than the skeletal wire sample, both with regards to mandibular total length (rigid: -0.7 mm, skeletal wire: -2.3 mm, $p < .05$) and with regards to mandibular body length (rigid: -0.6 mm, skeletal wire: -2.0 mm, $p < .05$).

When evaluating the relapse of total mandibular length about half of each sample stayed within 1 mm of its postsurgical total length (rigid: 14/26, skeletal wire: 4/9). But a much greater proportion of the

FIGURE 5.--Mandibular Linear Surgical Changes and Relapse



+7.0
+6.0
+5.0
+4.0
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
Amount of Change (mm)
T1
T2
T3
TOTAL LENGTH
(mm)
BODY LENGTH
(mm)
PROXIMAL SEGMENT LENGTH
(mm)
RIGID
WIRE
T1 PRESURGICAL
T2 PRESURGICAL
T3 RELAPSE

skeletal wire sample relapsed greater than 2 mm (rigid: 3/26, skeletal wire: 4/9), and the range of relapse was greater in the skeletal wire sample (rigid: -2.9 to +1.9 mm, skeletal wire: -6.0 to +0.1 mm). A slightly worse result for the skeletal wire sample was seen when evaluating the mandibular body length as compared to the mandibular total length. The proportion of patients staying within 1 mm of their postsurgical body length was much less for the skeletal wire sample (rigid: 17/26, skeletal wire: 2/9) and the proportion experiencing greater than 2 mm of relapse was much higher (rigid: 1/26, skeletal wire: 4/9). The range of relapse was much greater for the skeletal wire sample than for the rigid sample (rigid: -2.5 to +1.8 mm, skeletal wire: -9.1 to +1.8 mm).

The proximal segment length, as measured from articulare to gonion, showed small increases in length for both samples (rigid: +0.2 mm, skeletal wire: +0.4 mm, p: N.S.). Control of the proximal segment during surgery seemed to be slightly more accurate for the rigid sample, based upon the proportion of patients whose proximal segment length was within 1 mm of its presurgical value (rigid: 19/26, skeletal wire: 5/9) and the proportion of patients whose proximal segment length was within 2 mm of its presurgical value (rigid: 25/26, skeletal wire: 6/9). During the follow-up period the rigid sample experienced less relapse in proximal segment length than the skeletal wire sample (rigid: -1.0 mm, skeletal wire: -2.0 mm, p: N.S.). A comparable proportion of each sample stayed within 1 mm of the presurgical proximal segment length (rigid: 15/26, skeletal wire: 5/9). A much higher proportion of the skeletal wire patients had relapse in excess of 2 mm (rigid: 3/26, skeletal wire: 4/9) and the range of relapse was greater for the skeletal wire sample (rigid: -4.5 to +0.5 mm, skeletal wire: -6.2 to -0.1 mm).

Rigid Fixation Versus Skeletal Wire Fixation - Changes in Mandibular Angular Measurements

(Table 15: Measurements 1, 2 and 3; Figure 6)

The angular measurements of the proximal and distal segments produced the major area where there was a statistically significant difference between the surgical changes when comparing one sample to the other.

TABLE 15.--Rigid Fixation Versus Skeletal Wire Fixation - Angular Mandibular and Incisor Surgical Changes and Postoperative Relapse Comparison

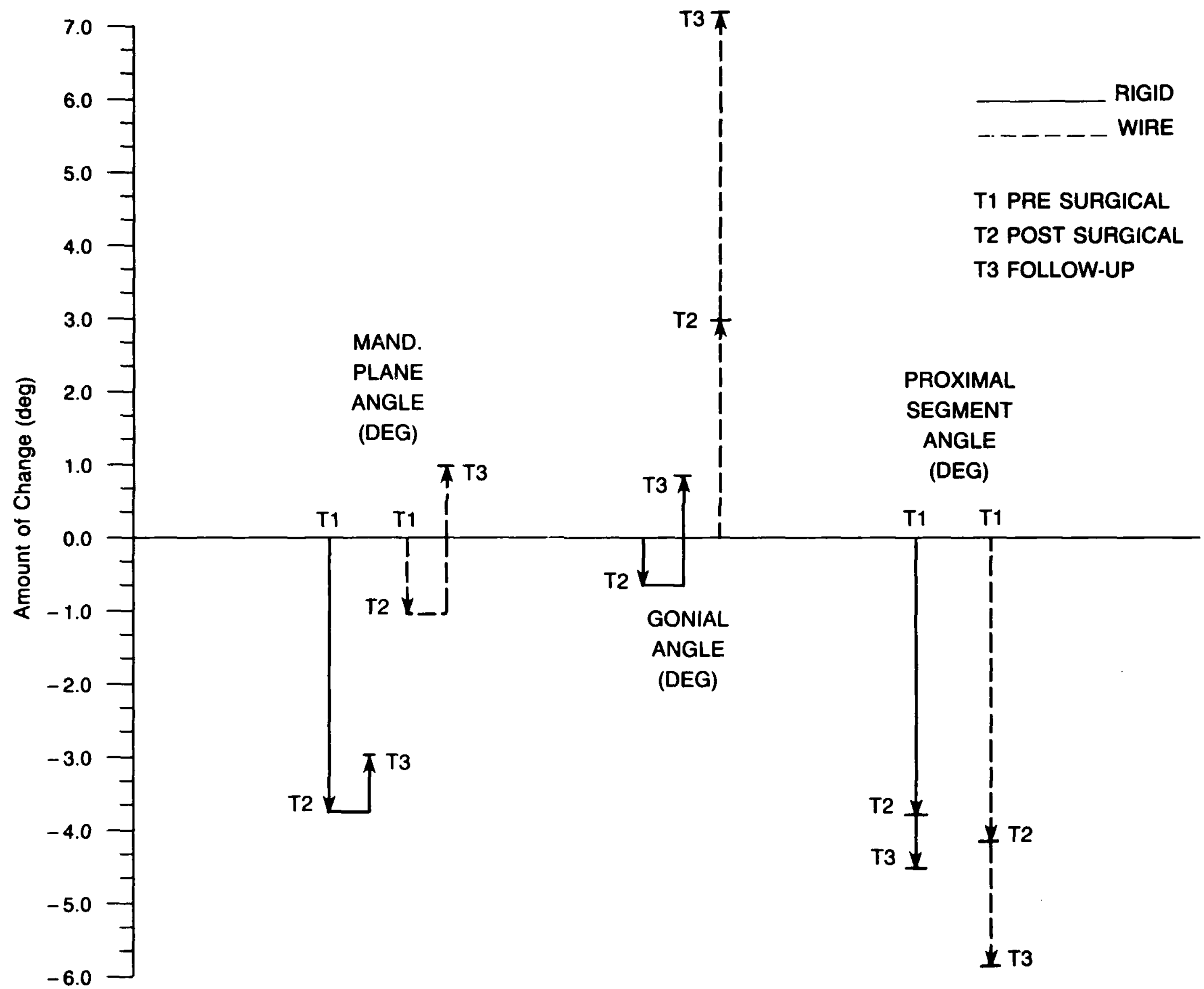
Variable	Surgical Changes Rigid	Skeletal	Sig	Post-Op Changes Rigid	Skeletal	Sig
1. Man Plane to SN (deg)	-3.8	-1.0	*	+0.8	+2.0	N.S.
2. Prox Seg to SN (deg)	-3.8	-4.2	N.S.	-0.7	-1.5	N.S.
3. Goniol Ang. (deg)	-0.7	+3.0	*	+1.5	+4.2	*
4. Upper 1 to SN (deg)	0.0	+0.6	N.S.	-1.1	-1.0	N.S.
5. Lower 1 to MP (deg)	-0.8	+1.3	*	-1.7	-0.8	N.S.

+ = anterior, inferior increase in value
- = posterior, inferior decrease in value

* = sig. at p < .05
** = sig. at p < .01
*** = sig. at p < .001
N.S. = not significant

94

FIGURE 6.--Mandibular Angular Changes and Relapse



RIGID
WIRE
T1 PRE SURGICAL
T2 POST SURGICAL
T3 FOLLOW-UP
Amount of Change (deg)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
MAND. PLANE ANGLE (DEG)
GONIAL ANGLE (DEG)
PROXIMAL SEGMENT ANGLE (DEG)
T1
T2
T3

Although the surgical changes in the proximal segment angle to SN as measured from articulare to gonion were comparable for the two samples (rigid: -3.8 deg., skeletal wire: -4.2 deg., p: N.S.), in the rigid sample a counterclockwise rotation of the distal segment in relation to the proximal segment was accomplished during surgery, whereas in the skeletal wire sample a clockwise rotation pattern of the distal segment in relation to the proximal segment was seen. This was indicated by the differences in the surgical change of the gonial angle (rigid: -0.7 deg., skeletal wire: +3.0 deg., $p < .05$) and was also reflected by the larger surgical decrease seen in the mandibular plane to SN for the rigid sample (rigid: -3.8 deg., skeletal wire: -1.0 deg., $p < .05$). A surgical decrease in the gonial angle occurred in over half of the rigid sample but in only a small number of the skeletal wire sample (rigid: 14/26, skeletal wire: 2/9). The proximal segment was rotated clockwise in relation to the SN line in all the patients in the skeletal wire sample and in the vast majority of the patients in the rigid sample (rigid: 24/26, skeletal wire: 9/9). The combination resulted in a decrease in the mandibular plane angle for 25 out of 26 in the rigid sample but a decrease in the mandibular plane angle in only five out of the nine patients in the skeletal wire sample.

The rigid fixation sample tended to have less relapse in these angular measurements during the follow-up period. This was most clearly shown when evaluating the relapse pattern in the gonial angle (rigid: +1.5 deg., skeletal wire: +4.2 deg., $p < .05$). Similar relapse patterns were seen for both samples when evaluating the proximal segment angle (rigid: -0.7 deg., skeletal wire: -1.5 deg., p: N.S.) and the mandibular plane angle (rigid: +0.8 deg., skeletal wire: +2.0 deg., p: N.S.) but the magnitude of the changes was less in the rigid sample. This rotational stability was also demonstrated by the fact that a much larger proportion of patients in the rigid sample stayed within 1 degree of their postsurgical value for the gonial angle (rigid: 15/26, skeletal wire: 2/9), the proximal segment angle (rigid: 10/26, skeletal wire: 3/9), and the mandibular plane angle (rigid: 13/26, skeletal wire: 2/9).

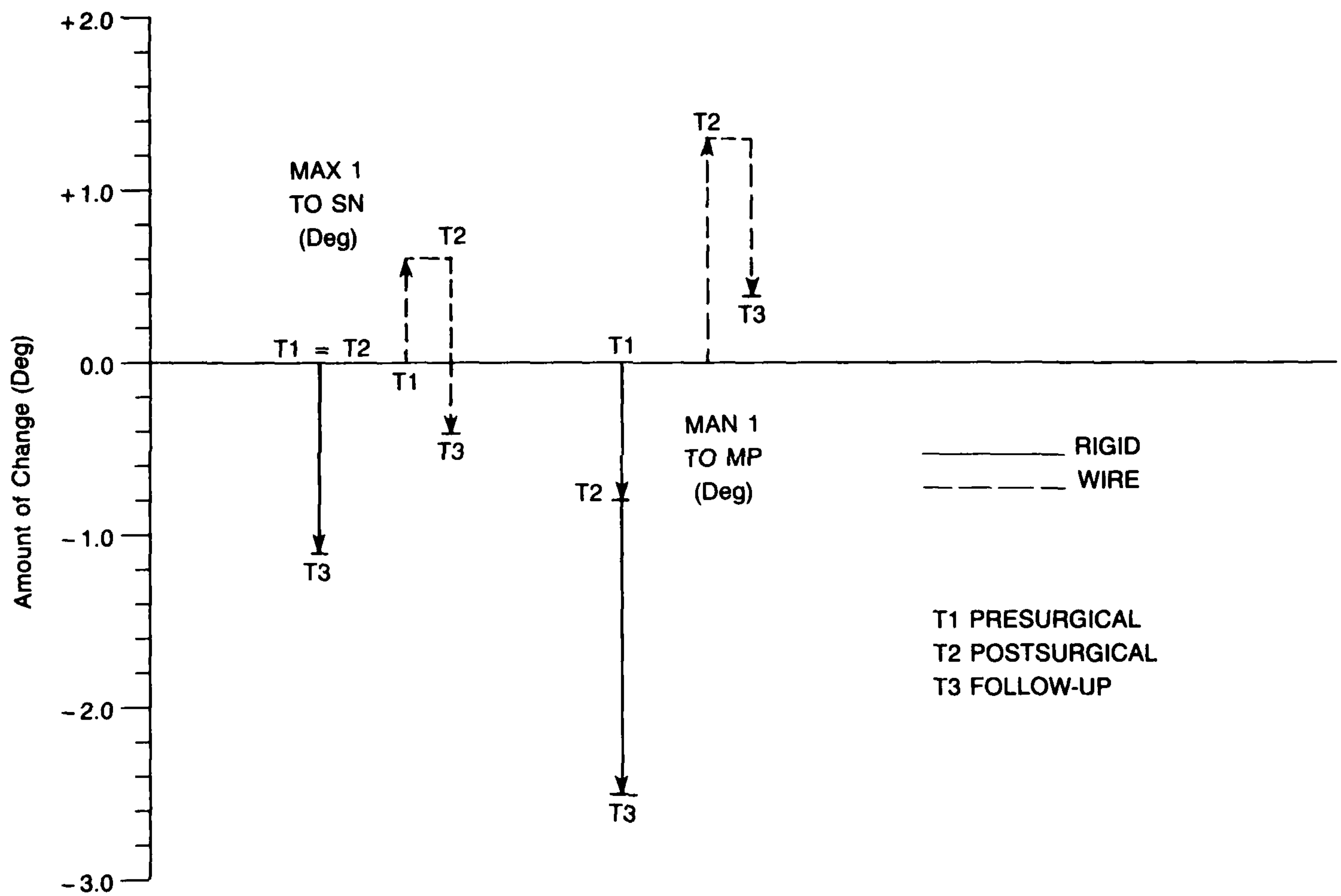
Rigid Fixation Versus Skeletal Wire Fixation - Changes in Incisor Angulation

(Table 15: Measurements 4 and 5, p. 93; Figure 7)

The mean changes in the upper incisor angulation to SN were small for both samples (rigid: 0.0 deg., skeletal wire: +0.6 deg., p: N.S.) and the relapse values were comparable (rigid: -1.1 deg., skeletal wire: -1.0 deg., p: N.S.). The range of values for the surgical change (rigid: -17.0 to +12.0 deg., skeletal wire: -8.0 to +16.5 deg.) and for the relapse (rigid: -10.0 to +7.0 deg., skeletal wire: -5.5 to +4.0 deg.) demonstrates the variability in these measurements.

The mean changes in the lower incisor angulation to the mandibular plane were also small during surgery (rigid: -0.8 deg., skeletal wire: +1.3 deg., $p < .05$) and during the follow-up period (rigid: -1.7 deg., skeletal wire: -0.8 deg., p: N.S.). A smaller range of values for the lower incisor angulation changes compared to the upper incisor angulation changes was evident during surgery (rigid: -6.0 to +3.5 deg., skeletal wire: -1.5 to +4.5 deg.) and during the follow-up period

FIGURE 7.--Incisor Angulation - Surgical Changes and Relapse


Amount of Change (Deg)
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
MAX 1
TO SN
(Deg)
T1 = T2
T3
T1
T2
T3
T1
T2
T3
T2
T3
MAN 1
TO MP
(Deg)
RIGID
WIRE
T1 PRESURGICAL
T2 POSTSURGICAL
T3 FOLLOW-UP

(rigid: -6.5 to +5.5 deg., skeletal wire: -6.0 to +3.0 deg.).

<u>Rigid Fixation Versus Skeletal Wire Fixation - Changes in Muscle Length Measurements</u>

(Table 16: Measurements 1, 2, 3, 4 and 5; Figure 8)

The surgical changes seen in the muscle lengths for both samples showed the same trends. The posterior facial height representing the pterygo-masseteric sling decreased during surgery for both samples (rigid: -0.5 mm, skeletal wire: -1.1 mm, p =N.S.). This value continued to decrease for both groups in the follow-up period as well (rigid: -1.0 mm, skeletal wire: -2.1 mm, p: N.S.) with the rigid sample showing a trend toward greater stability. The posterior facial height decreased in the follow-up period in the vast majority of patients in both groups (rigid: 20/26, skeletal wire: 7/9) and the range of values also demonstrates the trend for a decrease in posterior facial height (rigid: -7.5 to +1.8 mm, skeletal wire: -6.5 to +1.9 mm).

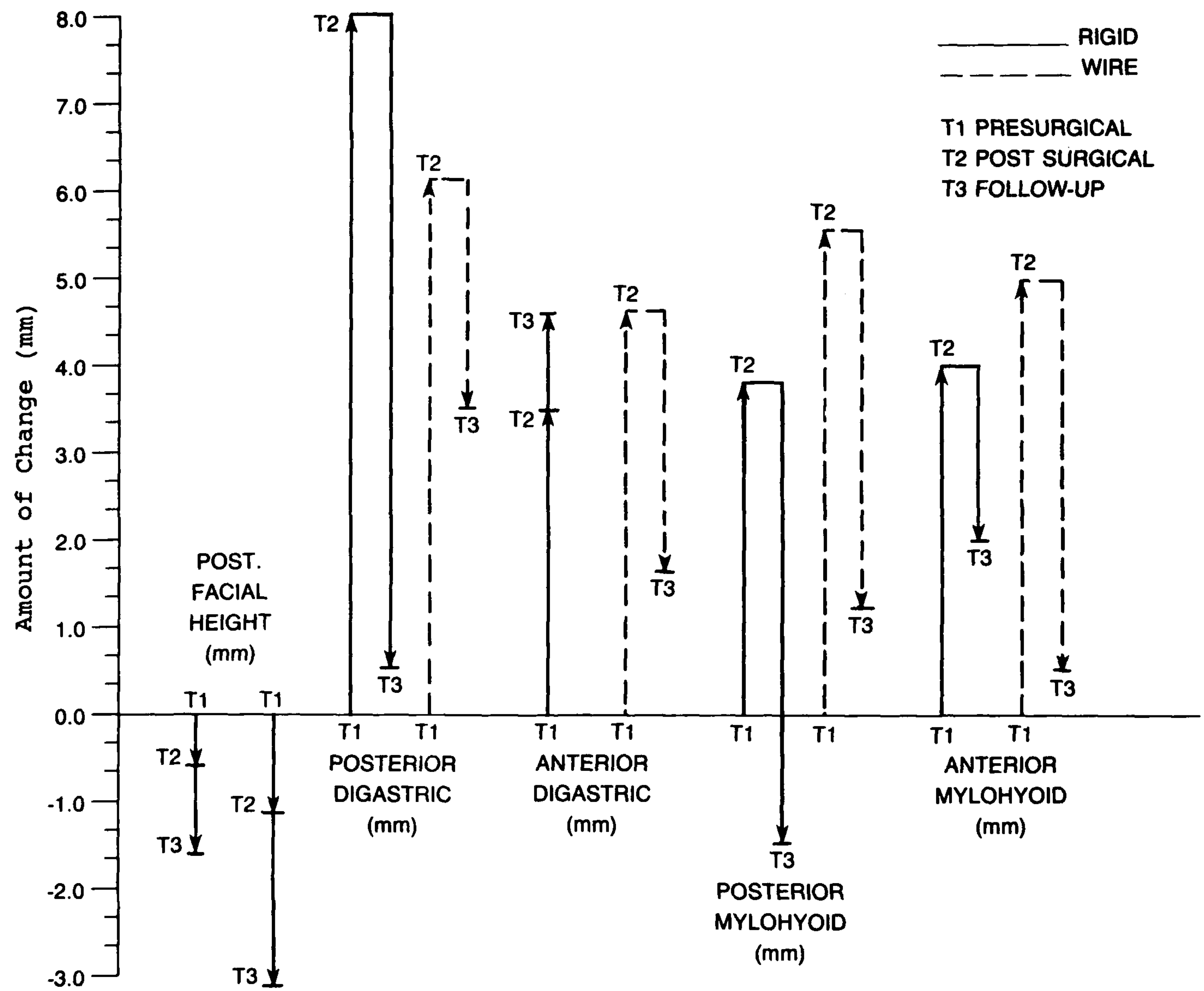
TABLE 16.--Rigid Fixation Versus Skeletal Wire Fixation - Muscle Lengths, Hyoid Position and Head Posture - Surgical Changes and Relapse Comparison

Variable	Surgical Changes Rigid	Surgical Changes Skeletal	Surgical Changes Sig	Post-Op Changes Rigid	Post-Op Changes Skeletal	Post-Op Changes Sig
1. Post. Facial Ht. (mm)	-0.5	-1.1	N.S.	-1.0	-2.1	N.S.
2. Post. Digastric (mm)	+8.0	+6.2	N.S.	-7.4	-3.6	*
3. Ant. Digastric (mm)	+3.4	+4.4	N.S.	+1.1	-2.7	*
4. Post. Mylohyoid (mm)	+3.7	+5.5	N.S.	-5.2	-4.3	N.S.
5. Ant. Mylohyoid (mm)	+4.1	+4.9	N.S.	-2.1	-4.4	N.S.
6. Hyoid Hor. (mm)	+6.1	+3.3	N.S.	0.0	+1.5	N.S.
7. Hyoid Vert. (mm)	+5.5	+4.9	N.S.	-8.1	-4.7	N.S.
8. C1 to Hyoid (mm)	+5.6	+5.6	N.S.	-5.1	-4.1	N.S.
9. Occ. to Atlas (mm)	+1.5	-0.1	*	-0.1	+1.6	**

+ = anterior
inferior
- = posterior
inferior

* = sig. at $p < .05$
** = sig. at $p < .01$
*** = sig. at $p < .001$
N.S. = not significant

FIGURE 8.--Muscle Lengths - Surgical Changes and Relapse



Amount of Change (mm)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
RIGID
WIRE
T1 PRESURGICAL
T2 POST SURGICAL
T3 FOLLOW-UP
POST. FACIAL HEIGHT (mm)
POSTERIOR DIGASTRIC (mm)
ANTERIOR DIGASTRIC (mm)
POSTERIOR MYLOHYOID (mm)
ANTERIOR MYLOHYOID (mm)
T1
T2
T3

During surgery the posterior digastric muscle length, as measured from the mastoid process to the hyoid bone, was increased in both samples (rigid: +8.0 mm, skeletal wire: +6.2 mm, p: N.S.), as was the anterior digastric length, as measured from the hyoid bone to the inferior lingual aspect of the mandibular symphysis, (rigid: +3.4 mm, skeletal : +4.4 mm, p: N.S.). During the follow-up period the changes in the two samples was quite different. The posterior digastric relapsed back toward its original length to a much greater extent in the rigid sample than in the skeletal wire sample (rigid: -7.4 mm, skeletal wire: -3.6 mm, $p < .05$). The anterior digastric, on the other hand, continued to increase in length during the follow-up period in the rigid sample while it relapsed back toward its original length in the skeletal wire sample (rigid: +1.1 mm, skeletal wire: -2.7 mm, $p < .05$). The tendency for relapse of greater than 1 mm in length was almost universal for the posterior digastric length (rigid: 25/26, skeletal wire: 7/9). The relapse in anterior digastric length demonstrated much more variability relapsing greater than 1 mm in only seven out of 26 in the rigid sample and six out of nine in the skeletal sample. The anterior digastric length increased during follow-up in 16 out of 23 patients in the rigid sample while this occurred in only two out of nine in the skeletal wire sample.

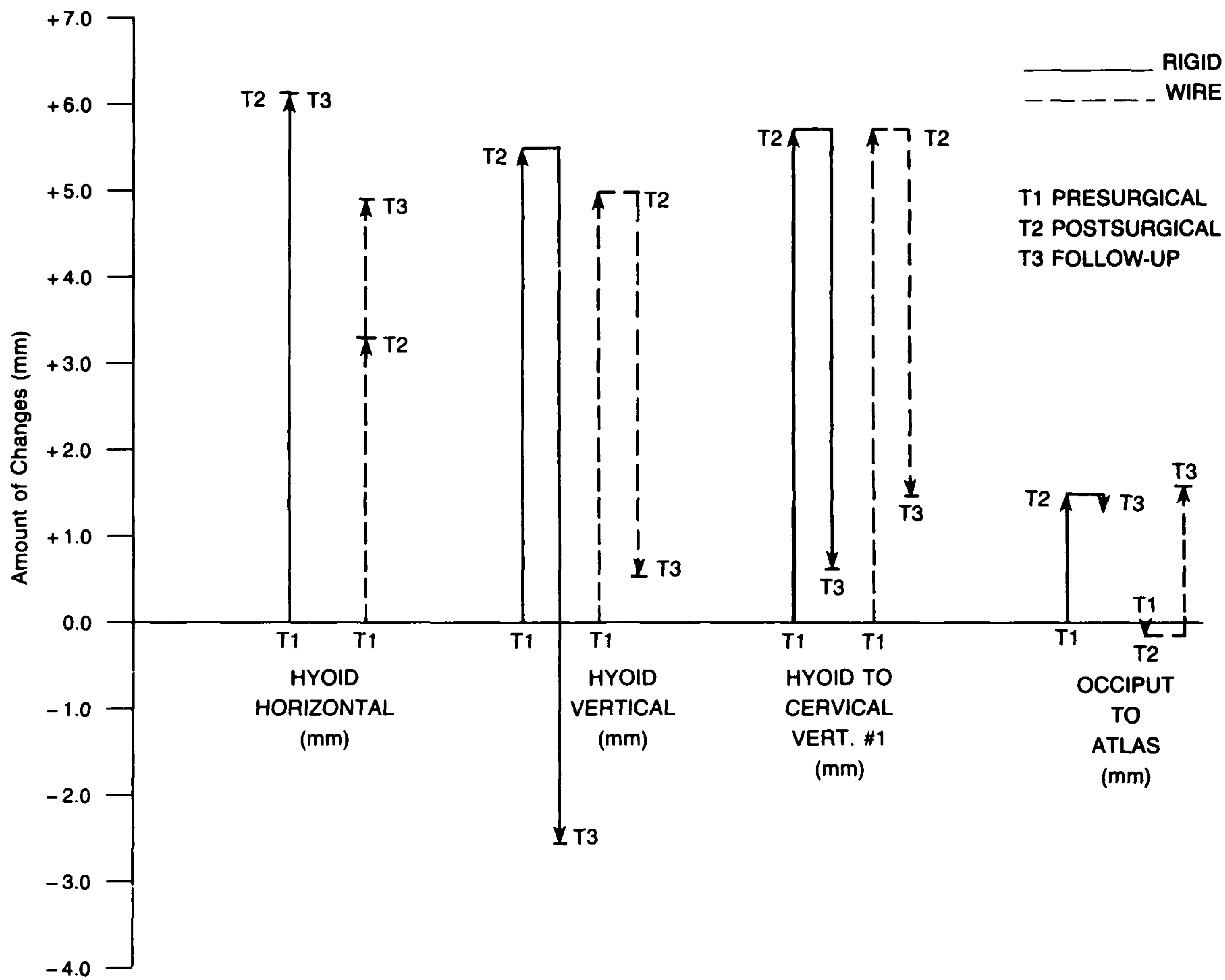
The surgical changes seen for both samples were very comparable when evaluating the posterior mylohyoid length, as measured from the hyoid bone to the apex of the first molar roots, (rigid: +3.7 mm, skeletal wire: +5.5 mm, p: N.S.) and the anterior mylohyoid length, as measured from the hyoid bone to the lingual aspect of the mandibular symphysis opposite the incisor root apex, (rigid: +4.1 mm, skeletal wire: +4.9 mm, p: N.S.). Similar relapse patterns were also seen for both samples for the posterior mylohyoid (rigid: -5.2 mm, skeletal wire: -4.3 mm, p: N.S.) and the anterior mylohyoid (rigid: -2.1 mm, skeletal wire: -4.4 mm, p: N.S.). Relapse occurred in the majority of the patients in both samples for both the posterior mylohyoid length (rigid: 22/26, skeletal wire: 7/9) and the anterior mylohyoid length (rigid: 16/26, skeletal wire: 7/9) but there was greater variability in the response for the anterior mylohyoid particularly in the rigid fixation sample.

<u>Rigid Fixation Versus Skeletal Wire Fixation - Changes in Hyoid Position and Head Posture</u>

(Table 16: Measurements 6, 7, 8 and 9, p. 102; Figure 9)

During surgery the hyoid bone tended to move anteriorly (rigid: +6.1 mm, skeletal wire: +3.3 mm, p: N.S.), inferiorly (rigid: +5.5 mm, skeletal wire: +4.9 mm, p: N.S.) and farther away from the first cervical vertebrae (rigid: +5.6 mm, skeletal wire: +5.6 mm, p: N.S.) for both samples. During the follow-up period the hyoid bone tended to be stable horizontally in the rigid sample and move slightly anteriorly in the skeletal wire sample (rigid: 0.0 mm, skeletal wire: +1.5 mm, p: N.S.). Vertically, the hyoid bone tended to relapse superiorly in both samples although the rigid sample tended to exhibit this relapse tendency to a greater extent (rigid: -8.1 mm, skeletal wire: -4.7 mm, p: N.S.). The distance to the first cervical vertebrae also tended to relapse strongly back toward its original position in both samples (rigid:

FIGURE 9.--Hyoid Position and Head Posture - Surgical Changes and Relapse


RIGID
WIRE
T1 PRESURGICAL
T2 POSTSURGICAL
T3 FOLLOW-UP
Amount of Changes (mm)
+7.0
+6.0
+5.0
+4.0
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
-4.0
T1
T2
T3
HYOID HORIZONTAL (mm)
HYOID VERTICAL (mm)
HYOID TO CERVICAL VERT. #1 (mm)
OCCIPUT TO ATLAS (mm)

-5.1 mm, skeletal wire: -4.1 mm, p: N.S.). The relapse of the hyoid bone tended to be extremely variable in the horizontal dimension for both samples (rigid range: -8.2 to +13.0 mm, skeletal wire: -3.7 to +9.8 mm) but a consistent tendency for relapse in the vertical dimension was seen in all patients as indicated by the number of patients in both samples that relapsed superiorly more than 1 mm (rigid: 24/26, skeletal wire: 7/9). All the patients in both samples experienced a relapse in the distance from the first cervical vertebrae to the hyoid bone during the follow-up period.

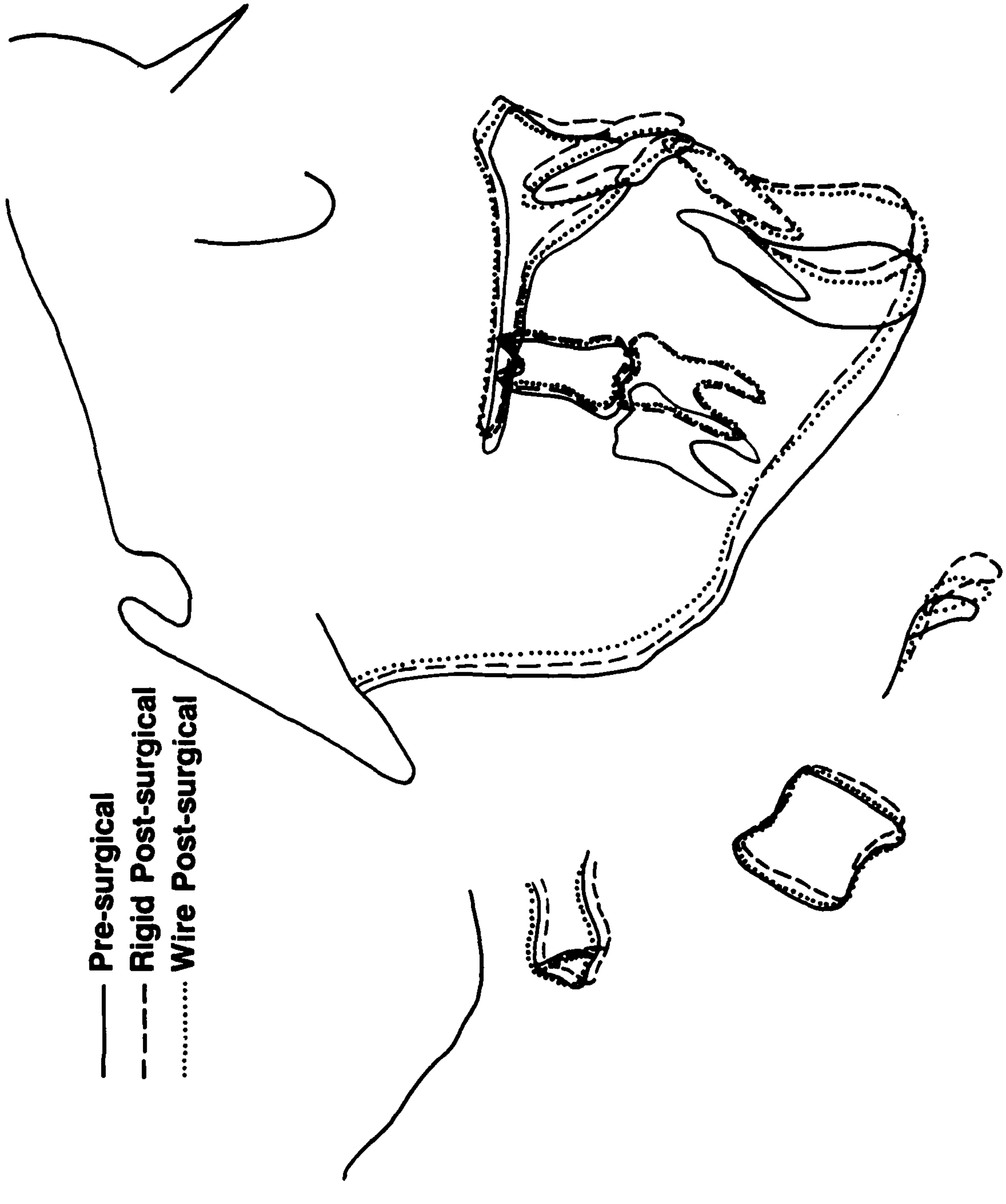
Both samples ended the follow-up period with a more forward head posture than before the surgery as evidenced by an increase in the distance from occiput to atlas, but this change in posture occurred at different times. The skeletal wire sample maintained the same posture during the surgical period, in contrast to the rigid sample which showed an increase in the occiput to atlas distance during surgery (rigid: +1.5 mm, skeletal wire: -0.1 mm, $p < .05$). During the follow-up period, the rigid sample maintained a stable head posture while the skeletal wire sample showed an increase in the occiput to atlas distance (rigid: -0.1 mm, skeletal wire: +1.6 mm, $p < .05$). The change in head posture occurred in the vast majority of patients with 23 of the 26 patients in the rigid sample experiencing a forward head posture during surgery and seven out of nine skeletal wire patients experiencing a change in head posture during the follow-up period.

CHAPTER V

DISCUSSION

The ability to minimize postsurgical skeletal and dental relapse or to accurately predict it is of paramount importance in the achievement of a stable esthetic and functional orthognathic surgical treatment result. This retrospective study directly compared two of the most commonly advocated fixation techniques which have been reported to minimize postsurgical relapse. The study involved a carefully selected sample from the office of one surgeon of patients who had undergone a maxillary impaction with a simultaneous advancement of the mandible. Although the number of patient records meeting all the criteria was much smaller for the skeletal wire fixation sample (nine for the skeletal wire fixation sample versus 26 for the rigid fixation sample), the demographic data including the mean follow-up period (Table 1, p. 21), the initial cephalometric values (Table 4, p. 33), and the surgical changes (Tables 13-16, p. 76,84,93,102; Figure 10) were very

FIGURE 10.--Surgical Composite - Rigid Fixation
Versus Skeletal Wire Fixation


Pre-surgical
Rigid Post-surgical
Wire Post-surgical

similar for the two samples. The results indicated that rigid fixation using plates and screws in the maxilla and bicortical screws to stabilize the mandibular segments provided superior stability overall when compared to skeletal wire fixation for double jaw surgery (Figure 11). These stability improvements were more dramatic in the mandible, especially for rotational control between the proximal and distal segments (Figure 12).

Maxillary Stability

The results of this study showed that the maxilla was very stable in the horizontal and vertical dimensions when rigid fixation was used. Even though the rigid sample was advanced 1.6 mm more than the skeletal wire sample (Table 13, p. 76; Figure 2, p. 78; Figure 10, p. 114), it showed less mean relapse (Table 13, p. 76; Figure 3, p. 82, Figure 11). There was no mean relapse either horizontally or vertically at A Pt. in the rigid fixation sample, while the skeletal wire fixation sample exhibited small relapse changes during

FIGURE 11.--Relapse Composite - Rigid Fixation Versus Skeletal Wire Fixation

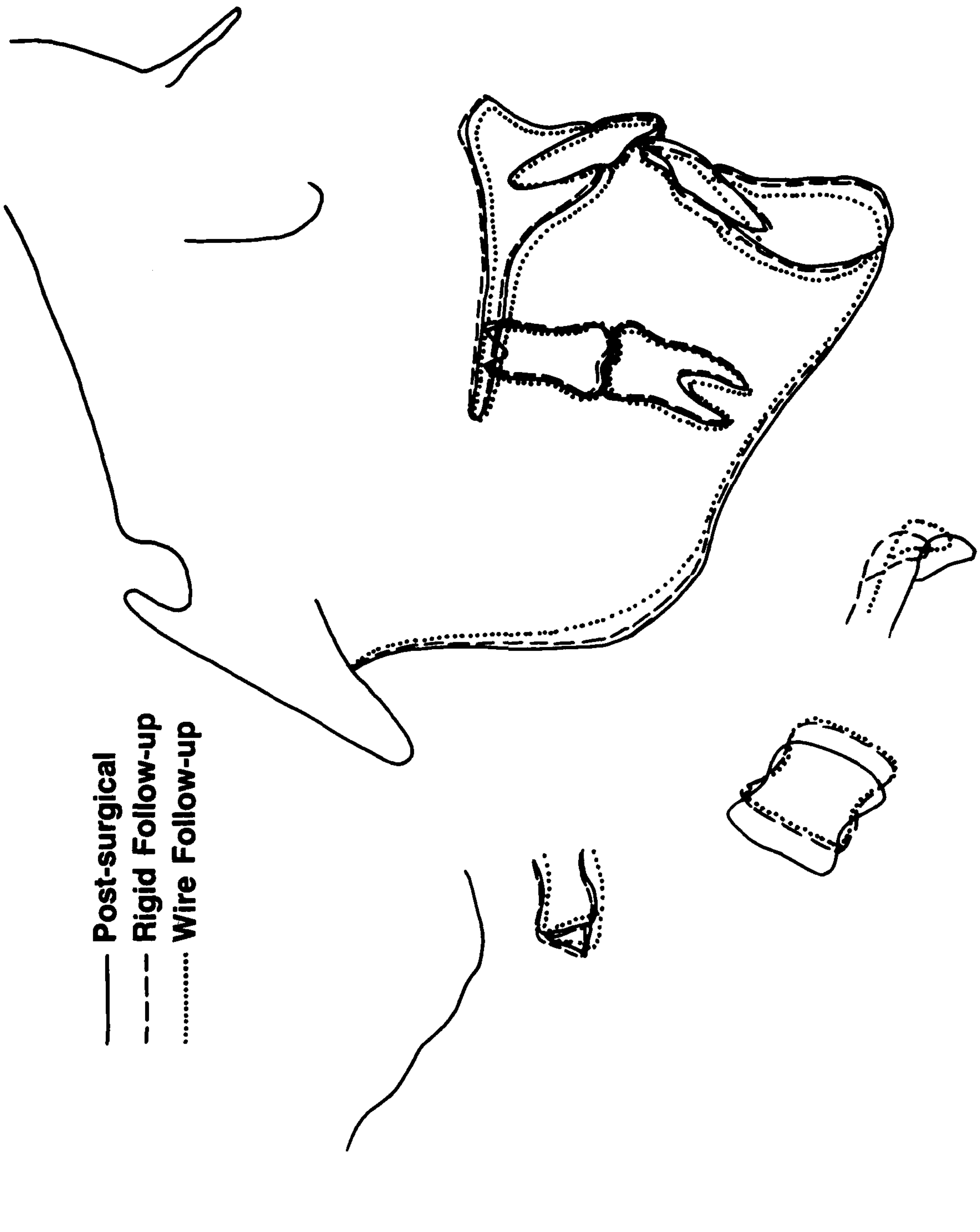
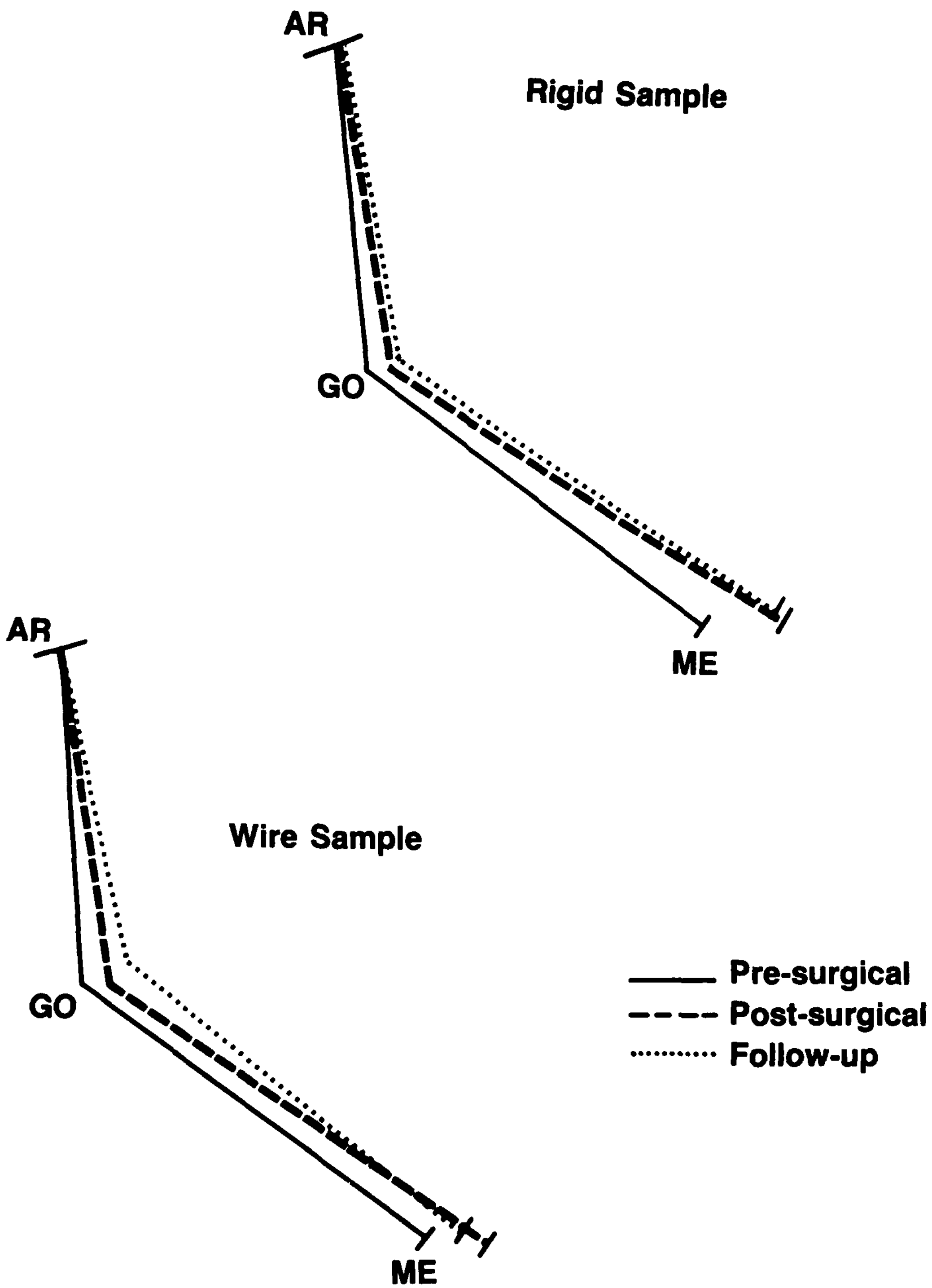

Post-surgical
Rigid Follow-up
Wire Follow-up

FIGURE 12.--Angular Changes of the Proximal and Distal Segments


AR
Rigid Sample
GO
ME
AR
Wire Sample
GO
ME
Pre-surgical
Post-surgical
Follow-up

the follow-up period which averaged 0.3 mm of relapse posteriorly and 0.8 mm inferiorly.

Early studies with wire fixation only (Wilmar 1974), including those with superior repositioning of the maxilla (Schendel et al. 1976) had demonstrated good stability of the maxilla with mean relapses of 1 mm or less in both dimensions. A more recent detailed study by Proffitt et al. (1987) of single jaw maxillary impactions also demonstrated overall good stability of the maxilla after superior repositioning using intraosseous wiring. Their sample had a slightly greater amount of impaction as measured at A Pt. (-3.82 mm versus -2.5 mm for this study's rigid sample and -2.2 mm for this study's skeletal wire sample) but underwent a slightly smaller maxillary advancement than the rigid sample in this study (+0.94 mm versus +1.9 mm). Their sample was less stable than the rigid sample in this study both horizontally (-0.93 mm versus 0.0 mm) and vertically (-0.32 mm versus +0.1 mm). Their sample showed a superior vertical relapse pattern (-0.32 mm superior vertical relapse) compared to the inferior pattern (+0.8 mm inferior vertical relapse) seen in the skeletal wire sample in this study . The results of this study indicated that the addition of skeletal suspension wires to intraosseous wiring did not increase maxillary vertical stability, while the use of rigid fixation did increase maxillary stability.

Proffit et al. (1987) indicated that 33 percent of the patients in their study showed postsurgical relapse greater than 2 mm during wire fixation or postfixation in the vertical dimension. In this study A Pt. stayed within 2 mm of its postsurgical position vertically in 25 out of 26 patients in the rigid fixation sample. The other patient had a superior vertical relapse of -2.1 mm. The skeletal wire fixation sample had two of nine patients (22 percent) which showed relapse greater than 2 mm vertically. Since the rigid fixation sample in this study had more patients with surgical changes greater than 2 mm than the wire sample in the study by Proffit et al. (1987) (approximately 60 percent versus 40 percent), and a much lower percentage of patients with relapse greater than 2 mm (4 percent versus 33 percent), the results indicated that there was a potential for increased maxillary stability with rigid fixation in that small percentage of patients that had a vertical relapse tendency using wire fixation techniques.

This study does not support the idea put forth by Ianetti et al. (1987) that the maxilla tended to be less stable if a mandibular procedure was performed concomitantly. To the contrary, when comparing the relapse values for this study with those for studies involving maxillary impactions only, the relapse values for the skeletal wire fixation sample were comparable to the relapses seen in the single jaw studies in magnitude and the values for this study's rigid sample was more stable. The relapse seen in the skeletal wire sample in this study was slightly inferior which was opposite in direction from the slightly inferior relapse seen in most single jaw studies but the values were too small to be of significance.

Other studies utilizing rigid fixation in the maxilla only (Harsha and Terry 1986; Luyk and Ward-Booth 1985) reported similar stability findings to this study with no relapse greater than 2 mm in either the horizontal or vertical dimension and with mean relapse values less than 1 mm reported in both dimensions. This study corroborated the earlier studies evaluating maxillary impaction only, which indicated that the use of rigid fixation improved the mean stability when compared to other types of fixation and virtually eliminated relapses greater than 2 mm.

<u>Mandibular Stability</u>

The relapse value for the mandible using skeletal wire fixation in this study was 26 percent as measured by the horizontal projection of B Pt. This value is comparable to the 26 percent relapse in mandibular projection reported by Lake et al. (1981), the 40 percent relapse reported by Kohn (1978) and the 25 to 50 percent relapse reported by Schendel and Epker (1980) for wire fixation of the mandible following mandibular advancement only. This value is greater than the 9 percent relapse reported by Ellis and Gallo (1986) who evaluated skeletal wire fixation following mandibular advancement only. It is also greater than the 14 percent relapse reported by Brammer et al. (1980) for double jaw surgery with wire fixation, although the majority of the patients in that study had suprahyoid myotomies performed and wore cervical collars in an effort to minimize relapse. It is comparable to the 27 percent reported by Wade (1988) in his double jaw study using wire fixation. The majority of the relapse in the skeletal wire fixation sample occurred across the osteotomy site in the body of the mandible which relapsed 2.0 mm (43 percent of its advancement). Unfortunately, the earlier mandibular studies did not measure the relapse in the body of the mandible separately so that no direct comparisons can be made with respect to the specific relapse location and pattern. The double jaw surgery study by Brammer et al. (1980) did measure mandibular body length in its 12 patient sample and showed an increase during the follow-up period of 0.4 mm or 10 percent. The relapse in that study occurred primarily in proximal segment as measured from articulare to gonion. It is possible the suprahyoid myotomies and soft cervical collars worn by the majority of the patients in the Brammer et al. (1980) study helped to prevent relapse across the osteotomy site. The fact that the skeletal wire sample showed greater relapse in this study than in the previous mandibular advancement studies (Ellis and Gallo 1986; Mayo and Ellis 1987) was disconcerting. It is possible that the skeletal fixation was not as effective in this study of double jaw cases since the circummandibular wires, in this instance, were attached to a splint which was interposed between the dentition across two "osteotomy segments" rather than to a fixed maxilla as utilized in one jaw surgery. The minimal maxillary relapse seen in this double jaw would not necessarily support this view but it is possible that the a decrease in the stability of the splint suspended between the skeletal wires was manifested to a greater degree in the mandible than in the maxilla. Therefore, although the reasons are unclear, the skeletal wire sample in this study showed mandibular relapse values greater than the values reported in an earlier study of double jaw surgery with wire fixation (Brammer et al. 1980), and greater relapse values than the values reported for skeletal wire fixation in mandibular advancements only. The mandibular relapse values reported here for the skeletal wire fixation sample are more comparable to those reported for mandibular advancements only using wire fixation alone.

The mandible was much more stable in the rigid fixation sample in this study showing a mean relapse of 0.5 mm or 6 percent of the B Pt. projection. This value is much lower than the 20 to 40 percent figures mentioned above for wire fixation and comparable to the 9 percent value reported by Ellis and Gallo (1986) for skeletal wire fixation in the mandible only. This is also comparable to the 8 percent reported by VanSickels et al. (1986) for rigid fixation following mandibular advancement surgery alone. It is superior to the 14 percent relapse in B Pt. projection reported by Brammer et al. (1980) and the 27 percent reported by Ward (1988) for double jaw surgery cases with wire fixation. The results of this study indicated that mean mandibular relapse values of less than 10 percent can be expected in double jaw cases which is comparable to the stability reported for rigid fixation in mandibular advancements alone.

The key to the increased stability of rigid fixation when compared to wire osteosynthesis or skeletal wire osteosynthesis may lie in the rotational control over the proximal and distal segments (Figure 12, p. 119). The idea of rotational control was mentioned by Lake et al. (1981) who reported greater relapse in mandibular advancements when the gonial angle increased during the follow-up period. Barer et al. (1987) using rigid fixation for mandibular advancements noted an increased stability for the gonial angle when compared to the values reported by Lake et al. (1981) and related this to their increased overall mandibular stability as measured by the projection of B Pt. In this study, the rigid fixation sample showed much less relapse in the gonial angle than the skeletal wire fixation sample (Table 15, p. 93; Figure 12, p. 119). The 4.2 degree relapse in gonial angle for the skeletal wire fixation sample in this study was twice the 1.9 degree relapse reported by Lake et al. (1981). The 1.5 degree relapse in the rigid sample of this study was also higher than the 0.3 degree relapse reported by Barer et al. (1980) in their study of rigid fixation for mandibular advancements only. In each case however, the rigid fixation sample of this study showed greater stability of the gonial angle and greater overall mandibular stability than for the comparable wire fixation sample, indicating that although angular relapse tends to be higher following double jaw surgery, the use of rigid fixation offers a real benefit in minimizing rotational relapse.

The advantage of rigid fixation for rotational control was confirmed by the fact that the correlation values for the skeletal wire sample were greater than for the rigid sample both (1) between the relapse in the gonial angle and the relapse in mandibular length ($r = -0.63$ for the skeletal wire sample and $r = 0.05$ for the rigid sample) and (2) between the relapse in gonial angle and the relapse in the projection at B Pt. ($r = -0.42$ for the skeletal wire sample and $r = 0.07$ for the rigid sample). In addition, the relapse in mandibular body length, the relapse in mandibular total length and the relapse in the gonial angle all were significantly greater in the skeletal wire fixation sample than in the rigid fixation sample ($p < .05$).

The rigid fixation sample demonstrated a greater ability to maintain rotational control of the mandibular plane angle as demonstrated by the fact that the rigid fixation sample showed a greater decrease in mandibular plane angle during surgery and a smaller relapse in the follow-up period than the skeletal wire sample. All of the results indicated the greater rotational stability of the rigid fixation sample.

It is interesting to note that the surgeon realized the rotational advantage of rigid fixation and planned his surgical procedures for the rigid fixation sample to include a counterclockwise rotation of the distal segment with respect to the proximal segment, but did not plan his treatment for the skeletal wire fixation sample in this fashion.

The potential for greater alteration in the condyle to fossa relationship has been mentioned as a potential disadvantage of rigid fixation by Thomas et al. (1986) and by Kundert and Hadjianghelou (1980) who found larger condylar displacements when using rigid fixation as compared to wire osteosynthesis. In an effort to determine whether this concern was manifested in increased condylar or fossa remodeling, the proximal segment length from articulare to gonion was measured in this study. The gonial arc method described by Kohn (1978) and used by Lake et al. (1981) was not utilized since condylion was not visible in many of the radiographs. It was felt that measuring changes in the proximal segment length and in the proximal segment angle would allow an adequate means of evaluating the movements of the proximal segment. The proximal segment length increased slightly during surgery in both groups (+0.2 mm for the rigid sample and +0.4 mm for the skeletal wire sample) indicating only slight condylar distraction. During the follow-up period, this length decreased half as much for the rigid sample (-1.0 mm) as for the skeletal wire sample (-2.0 mm). Since this follow-up reduction was more than any surgical distraction, this would indicate that some condylar or fossa remodeling may have occurred in both groups during the first year postsurgically and that the remodeling was more pronounced in the skeletal wire sample than the rigid fixation sample. Brammer et al. (1980) also measured the surgical and follow-up changes in the proximal segment length as measured from articulare to gonion, and found a +3.6 mm distraction during surgery and a -3.9 mm decrease in length during the follow-up period. These measurements indicated greater condylar distraction than seen in either of the samples in this study and, perhaps, less remodeling during the follow-up period since the overall change in length was less than in this study. More research is indicated to determine whether the changes seen here are indicative of a remodeling of the joint or a remodeling of the gonial angle and whether they represented a detrimental effect of the surgery. Gonial angle remodeling was seen in this study and also reported by Kohn (1978) but since the proximal and distal segments were each regionally superimposed to obtain the location gonion for this study, it was felt the changes seen do not simply represent remodeling of the gonial angle but do reflect a true decrease in proximal segment length. If the changes did represent remodeling of the mandibular condyle or fossa, the results indicate that this remodeling tended to occur to a greater extent in the skeletal wire fixation sample. The use of rigid fixation has been reported to be beneficial to joint function by allowing earlier mandibular mobilization and a greater postoperative range of motion when compared to wire fixation with its associated four to six weeks of intermaxillary fixation (Aragon and Van Sickels 1987). Further studies regarding the effect of rigid versus wire fixation on the temporomandibular joint would be valuable to correlate morphological changes and function.

<u>Incisor Stability</u>

Several studies have shown the potential for dental relapse associated with the skeletal relapse. The dental relapse has been reported both during intermaxillary fixation (McNeill et al. 1973; Ive et al. 1977; Schendel and Epker 1980; Lake et al. 1981) and during the follow-up period after the release of fixation (Kohn 1978; Lake et al. 1981). This study utilized measurements of the upper and lower incisor angulation to evaluate this aspect of relapse. The upper incisor showed little mean change during surgery (rigid sample = 0.0 deg., skeletal wire sample = +0.6 deg.), and a small postsurgical change (rigid sample = -1.1 deg., skeletal wire sample = -1.0 deg.).

These small follow-up movements did not correlate with any skeletal relapse values.

The surgical change in the lower incisor angulation was different for the two samples with the lower incisor becoming slightly more proclined in the skeletal wire fixation sample (+1.3 deg.) during the surgical period when compared to the rigid fixation sample (-0.8 deg.). A similar and slight uprighting occurred in both samples during the follow-up period (rigid sample = -1.7 deg., skeletal wire sample = -0.8 deg.) Previous studies (McNeill et al. 1973, Lake et al. 1981) suggested that mandibular relapse had been associated with incisor compensations which tend to mask the skeletal changes especially during fixation. This study, like the results of Ive et al. (1977) could not confirm this suggestion; however, the skeletal wire sample in this study was not measured both at the beginning and at the end of the fixation period as was done in previous studies. The lower incisor changes during the follow-up period were small for both samples despite the large differences in skeletal relapse patterns for the two samples. These changes were probably the result of the orthodontists' efforts during the follow-up period to maintain proper incisor angulation. Since the overjet and overbite were not measured, a complete understanding of the dental changes associated with the skeletal relapse patterns was not possible in this study.

Muscular Changes

Since the forces exerted by the facial and cervical musculature, in general, and the suprahyoid musculature, in particular, have been implicated by many authors as a cause of relapse (Poulton and Ware 1973; McNamara et al. 1978; Ellis and Carlson 1983; Epker et al. 1978), this study used several cephalometric landmarks designed to approximate the surgical and relapse changes in the resting length of certain muscles. Although the results could not reveal the dynamic effects that muscle function may have had on the relapse pattern, the surgical changes and follow-up relapse patterns were indicative of certain trends.

All of the muscle length measurements except for the posterior facial height and the anterior digastric length increased significantly during surgery ($p < .05$ to $p < .001$) and then relapsed back during the follow-up period. In general, the muscle lengths were stretched from 9 percent to 20 percent during surgery, with most increases staying in the 9 percent to 15 percent range. The relapse that occurred brought the final muscle lengths back to within 5 percent of their original length.

The amount of relapse of the anterior mylohyoid length, measured from the hyoid bone to the lingual aspect of the mandibular symphysis opposite the lower incisor, and posterior mylohyoid length, as measured from the hyoid bone to the apex of the mandibular first molar roots, did show a moderate correlation to the amount of surgical stretching for both samples (range of r values from -0.56 to -0.79). The relapse of these mylohyoid lengths was associated with a 5 mm superior movement of the hyoid bone during the follow-up period for both samples. The posterior digastric length, as measured from the hyoid bone to the mastoid process, also showed a strong propensity to return to its original length after surgical lengthening (rigid sample = 9 percent stretch, relapse to within 1 percent of original length, skeletal wire sample = 7 percent stretch, relapse to within 4 percent of original length). The correlations were not quite as strong as for the mylohyoid lengths (r values were -0.59 for rigid sample and -0.51 for the wire sample). Other than a weak correlation between the relapse of the posterior digastric and the relapse of the mandibular plane angle for the skeletal wire sample, and a weak correlation between the relapse of the posterior mylohyoid and the relapse of the mandibular plane angle for the skeletal wire fixation sample, the follow-up changes in the lengths of the posterior digastric and the posterior and anterior mylohyoid showed no correlations to any of the skeletal relapse values measured or to the amount of surgical change for any of the hard tissue measurements (all r values less than 0.50).

The posterior facial height representing the pterygomasseteric sling decreased in both samples during surgery (rigid sample = -0.5 mm, skeletal wire fixation

= -1.1 mm) and then continued to decrease during the follow-up period (rigid sample = -1.0 mm, skeletal wire = -2.1 mm). This result is consistent with results of several other studies which have shown a propensity for a decrease in posterior facial height during the follow-up period of from 2 to 4 mm for wire osteosynthesis (Lake et al. 1981; Kohn 1978), and smaller decreases of 0.2 to 0.4 mm reported for rigid fixation (McDonald et al. 1987; Barer et al. 1987) following mandibular advancements alone. The greater decrease in posterior facial height for the skeletal wire sample as compared to the rigid fixation sample in this study showed the potential for increased posterior stability using rigid fixation. The use of rigid fixation for downgrafting the maxilla in patients with a vertical maxillary deficiency may have potential benefit. However, since this study showed a decrease in posterior facial height during the follow-up period after a maxillary impaction even with rigid fixation, any prediction for success with maxillary downgrafting must remain guarded until further studies are completed.

Stretching of the anterior digastric length or suprahyoid muscle complex has also been named as a potential cause of relapse following mandibular advancement (Poulton and Ware 1973; Schendel and Epker 1980; Ive et al. 1977). Various procedures and devices from cervical collars (Poulton and Ware 1973) to suprahyoid myotomies (Ellis and Carlson 1983) have been advocated to counteract the forces exerted by the stretched muscles. In this study, the relapse patterns in the anterior digastric length, as measured from the hyoid bone to the inferior lingual aspect of the mandibular symphysis, showed the greatest difference between the rigid and skeletal wire samples of any muscle length change. In the rigid sample, the anterior digastric length continued to increase by 1.1 mm during the follow-up period, whereas the skeletal wire sample showed a relapse or decrease of 2.7 mm. It appeared that the rigid fixation was stronger than the relapse forces generated within the anterior digastric complex, but the skeletal fixation was not. Studies have shown that mature muscle can permanently adapt to increases in length by increasing the number of sarcomeres (Goldspink 1980), by adaptations in morphology (Faulkner, Maxwell and White 1978), and by stretching of the connective tissue in the muscle-tendon interface and muscle-bone interface (Carlson et al. 1987). Whether some or all of these changes occurred in the anterior digastric muscle of the rigid fixation patients is impossible to determine. It should be noted that the long term stretching of the anterior digastric length was only 12 percent of its original length, so the postulated "15 percent maximum stretch" mentioned by Epker et al. (1978) was not violated. For all the muscles studied except the anterior digastric, the long term increase in length did not exceed 5 percent of their initial length, so the anterior digastric would appear to be the most easily lengthened muscle. It must be recognized that the attempts to measure muscle effects in this study were based upon static measurements from cephalometric radiographs and may not represent the relapse pressures applied by the muscle groups in function.

Changes in Hyoid Position and Head Posture

The 6.1 mm forward movement of the hyoid bone during the surgical period in the rigid sample was greater than the 4.8 mm forward movement in the skeletal wire sample in this study and greater than the 3.8 mm forward movement found by LaBanc and Epker (1984) for mandibular advancements only. Schendel and Epker (1980) also reported the advancement of the hyoid bone in relationship to the cervical vertebrae with a corresponding neck flexure during surgery and a subsequent posterior relapse. The surgical movement of the hyoid bone in this study of double jaw surgery patients was similar to previous one jaw studies. However, the posterior relapse of the hyoid bone position was less than that seen in one jaw studies (0.0 mm for the rigid sample and +1.5 farther anterior movement in the skeletal wire sample versus -1.3 mm of relapse for wire sample of LaBanc and Epker (1984)).

The hyoid bone moved inferiorly during surgery (5.5 mm for the rigid sample and 4.9 mm for the skeletal wire sample) and superiorly following surgery (8.1 mm for the rigid sample and 4.7 mm for the skeletal wire sample) to a much greater extent than the 2 mm vertical changes found in the evaluations by LaBanc and Epker (1984). Differences in the vertical movements might be expected because of the simultaneous impaction of the maxilla in both samples used in this study. The greater changes in the vertical position of the hyoid bone in the rigid sample when compared to the skeletal wire sample may have been one of the accommodations that allowed the relapse in muscle lengths seen in both samples without the relapse in mandibular skeletal segments seen in the skeletal wire sample. The results indicated that there was a long term modification in the position of the hyoid bone as a result of orthognathic surgery in both fixation samples.

There was also a long term modification of the head posture as a result of orthognathic surgery, as evaluated by measuring the distance from occiput to atlas. Both samples showed a permanent forward head posture (or possibly anterior neck flexure) as a result of surgery, represented by an overall increase in the distance from occiput to atlas from the presurgical to follow-up period in both samples (+1.4 mm for the rigid sample, +1.5 mm for the wire sample). This change occurred almost entirely during surgery for the rigid fixation but was a more gradual process for the skeletal wire fixation sample, occurring during the follow-up period. In contrast, Schendel and Epker (1980), in their study of mandibular advancements reported that a similar change in head posture occurred during surgery, but was short lived. The change in head posture seen in this study may represent another adaptation that allows the maintenance of resting muscle lengths while minimizing skeletal relapse. Whether this change in head posture requires a permanent alteration in the activity of the muscles of the cervical region and upper back would be an interesting area for further research.

Discussion of Relapse Theories

Several measurements were included in this study to quantify variables that would allow the testing of the commonly held theories for the cause of relapse. The major theories evaluated were: (1) the amount of postsurgical skeletal relapse is related to the amount of surgical change, (2) postsurgical skeletal relapse is related to the stretching and subsequent relapse of the muscles of mastication, cervical muscles and suprahyoid muscles, (3) postsurgical skeletal relapse is related to improper seating of the condyle, (4) postsurgical skeletal relapse is related to a counterclockwise rotation of the mandible during surgery, and (5) postsurgical skeletal relapse is related to the type of fixation utilized.

1. The hypothesis that the amount of skeletal relapse is related to the amount of surgical change was mentioned by Ive et al. (1977), and the magnitude of relapse was listed as a primary factor in determining stability by Lake et al. (1981), who found an r value of 0.6 for the correlation between skeletal relapse and the amount of surgical advancement for mandibular advancements alone. This study of double jaw surgery patients only weakly supported the idea that postsurgical skeletal relapse was related to the amount of surgical change. The correlations between skeletal relapse and surgical movement were greater for the skeletal wire sample than for the rigid sample. There was no correlation found between the skeletal relapse of

the maxilla in a vertical direction and the amount of surgical movement in that direction for the rigid fixation sample ($r = -0.16$) and there was only a weak correlation for the skeletal wire sample ($r = -0.55$). There were weak correlations between the amount of mandibular advancement and the amount of mandibular skeletal relapse for the rigid fixation sample ($r = -0.04$ for the horizontal projection of B Pt., $r = -0.56$ for the total mandibular length and $r = -0.44$ for the mandibular body length). The correlation between the skeletal relapse of the horizontal projection B Pt. and its surgical advancement was higher for the skeletal wire fixation sample ($r = -0.69$), but was weak for the correlation between advancement and relapse of the mandibular total length ($r = -0.41$) where gonial angle relapse had a higher correlation value. Dividing the rigid sample into two subsets of < 5 mm and $\geq$ 5 mm did show a statistically significant increase in the amount of relapse in mandibular body length for the advancements > 5 mm (-0.1 mm for advancements < 5 mm versus -1.0 mm for advancements > 5 mm, $p < .01$) but this trend did not continue when those patients with advancements > 10 mm were evaluated. Thus, though the relationship between surgical movement and subsequent relapse appeared to be true to a moderate degree in the skeletal wire sample, and to some extent in the rigid fixation sample, it was by no means a simple linear relationship. Future studies may want to evaluate the relationship using more sophisticated analyses.

2. The hypothesis that the force generated by muscles lengthened during surgery, especially the suprahyoid group of muscles, causes skeletal relapse is frequently stated. This theory began with early articles by Poulton and Ware (1973) and McNeill et al. (1973) and has been restated in the majority of the studies on relapse since that time. Although studies involving the use of cervical collars (Poulton and Ware 1973), and suprahyoid myotomies (Ellis and Carlson 1983) designed to lessen relapse have supported this theory for skeletal relapse following mandibular advancement, none of the large cephalometric stability studies have included muscle lengths in their investigations. No studies of double jaw surgery have included muscle length measurements. The majority of the muscle lengths

measured in this study did show relapse back toward their original length and a moderate degree of correlation was found between the amount of muscle lengthening during surgery and the amount of muscle shortening during the follow-up period ($r = -0.51$ to -0.79). But there were not any strong correlations between the relapse of any skeletal measurements and the relapse of any of the muscle lengths. The relapse in ANB did show a moderate correlation with the relapse in posterior mylohyoid length ($r= +0.64$) and the relapse in posterior digastric length ($r= +0.61$) for the skeletal wire sample only but no r values exceeded +0.3 for the rigid fixation sample. The anterior digastric muscle length which has often been mentioned as a cause for mandibular relapse following advancement showed the greatest ability of any of the muscles to adapt to a permanent increase in length. The anterior digastric muscle maintained a 12 percent increase in length in the rigid sample, while all other muscle lengths relapsed to within 5 percent of their original lengths. Whether the lack of correlations between muscle length relapse and skeletal relapse seen in this study reflect a difference in the type of surgical procedure (double jaw versus single jaw) or whether it indicates that static muscle lengths do not accurately reflect the effects of active muscle groups is impossible to say. It is logical to assume that the forces generated by the stretching of muscles and their associated connective tissue components should have an effect on stability, but this was not verified by the measurements in this study.

3. Many studies have indicated that lack of control of the proximal segment due to improper seating of the condyle is a major cause of relapse (Kohn 1978; Epker et al. 1978; Lake et al. 1981), but that was not the case in this study. Proximal segment control was evaluated by measuring the length of the proximal segment, from articulare to gonion, which showed only slight distraction during surgery (+0.2 mm for the rigid sample; +0.4 mm for the skeletal wire sample). Although this measurement was a crude means of assessing proximal segment position which did not take into account the effects of proximal segment rotation on the apparent length, major distraction of the condyle should have

been evident. In general, both samples showed a slight tendency for distraction of the condyles during surgery, with a subsequent relapse in proximal segment length during the follow-up period, but the relapse in the proximal segment length did not correlate with the relapse in the mandibular length or the horizontal projection of the mandible at B Pt. These results were in contrast to the excellent single jaw study by Lake et al. (1981) and double jaw study by Brammer et al. (1980), which both related relapse of mandibular projection to relapse in the proximal segment. Both of these studies, however, demonstrated larger surgical changes in their measurements of condylar position. In this study, it appears that the surgeon took great care to ensure that the condyle was properly seated in the fossa and this care may have resulted in the small effect that follow-up condylar changes had on the overall relapse pattern.

4. Many authors have cautioned that counterclockwise rotation movements in the mandible are a cause of relapse both in single jaw mandibular surgery (McNeill et al. 1973; Epker et al. 1978) and in double

jaw surgery (Brammer et al. 1980). However, a greater relapse pattern in the mandible was not associated with a counterclockwise rotation of the mandible during surgery for either sample of patients in this study. The patients who experienced a counterclockwise rotation of the distal segment with respect to the proximal segment were primarily in the rigid fixation sample, although two patients out of nine skeletal fixation patients showed this pattern to a small degree (less than 1.5 degrees). The rigid sample was very stable despite the frequency of counterclockwise surgical movements. This is not to say that rotational control between the proximal and distal segments is not important. On the contrary, as discussed previously, lack of rotational control with large increases in the gonial angle during the follow-up period was one of the major problems with the skeletal wire fixation method when compared with the rigid fixation sample. Larger relapses could have been expected for the patients with counterclockwise rotations if they had been performed in the wire fixation sample. Another reason that counterclockwise rotations did not result in higher relapse values for this study compared to studies of mandibular advancements alone is that in this study, since the maxilla was simultaneously impacted, there was no increase in posterior facial height as a result of the counterclockwise rotation. It may be that the increase in posterior facial height, not the rotational direction, was the prime cause of relapse in the earlier mandibular advancement studies of counterclockwise rotation.

5. Many authors have advocated different types of fixation to improve stability, such as upper and lower border wiring techniques (Booth 1981), threaded Steinman pins (Wolford and Hilliard 1981), skeletal wire fixation (Schendel and Epker 1980) and rigid fixation (Champy 1978; Spiessl 1982). Comparing the last two types of fixation, skeletal wire fixation versus rigid fixation, was the primary purpose of this study and it was found that the type of fixation used did make a difference. The rigid fixation was more stable than the skeletal wire fixation. This increase in stability was manifested to a small degree in the maxilla and became significant in the mandibular relapse patterns,

especially the relapse in mandibular total length, mandibular body length, and the gonial angle. The maintenance of angular stability between the proximal and the distal segments of the mandible was particularly noticeable when comparing the rigid fixation sample to the skeletal wire fixation sample.

This study showed that rigid fixation was more stable than skeletal wire fixation, but it did not provide any clear correlations that would verify any of the most common relapse theories, indicating that the cause of skeletal relapse is multifactorial and that the interplay between the different factors can vary from one individual to another. Many factors which should have had an obvious effect on the stability of the skeletal segments, such as the thickness of the bone in the area of the osteotomy site, and the degree of bony approximation obtained during surgery, have not been quantified or even recorded in stability studies discussed here. The type of musculature and the bite forces exerted by the individual may be other areas that had strong effects on stability. Recording and attempting to quantify some of these other variables may lead, if not to improved stability, at least to an improved ability to predict results when planning treatment for a surgery patient. It is hoped that future research efforts can be directed, not only at determining better ways to improve the overall stability for a sample of patients, but also to identify the factors that would allow the ability to pre-surgically predict instability in that small percentage of individuals with a propensity for skeletal relapse.

CHAPTER VI

SUMMARY OF RESULTS

This retrospective study was designed to compare the stability of rigid fixation versus skeletal wire fixation for patients undergoing orthognathic surgical correction of vertical maxillary excess combined with mandibular deficiency, and to evaluate the validity of some of the commonly held theories concerning the causes of relapse. The study involved 26 patients in the rigid fixation sample and nine patients in the skeletal fixation sample who had all undergone maxillary impactions simultaneously with mandibular advancements performed by one surgeon. The average follow-up period for both samples was 15 months.

Based upon 19 linear and eight angular measurements, the following observations were made:

1. The maxilla was relatively stable for both fixation techniques, remaining within 1 mm of its postsurgical position, horizontally and vertically.

2. The maxilla was more stable in the rigid fixation sample than the skeletal wire fixation sample. In addition, rigid fixation eliminated all relapse greater than 2mm.
3. The mandibular length was significantly more stable in the rigid fixation sample than in the skeletal wire fixation sample.
4. The use of rigid fixation maintained significantly better rotational control of the gonial angle between the proximal and distal segments. This rotational control appeared to be a major factor in the increased overall stability of the rigid fixation sample when compared to the skeletal wire fixation sample.
5. Proximal segment position was well controlled during surgery in both samples. The skeletal wire fixation sample showed a greater decrease in the length of the proximal segment than the rigid fixation sample during the follow-up period.

6. All muscle length measurements except the posterior facial height and the anterior digastric length increased from 9 % to 20 % during surgery, then relapsed back to within 5 % of their original length during the follow-up period.
7. The posterior facial height decreased less than 0.5 mm during surgery, then continued to decrease during the follow-up period. The rigid fixation sample was more stable showing only 1 mm further decrease versus 2 mm for the skeletal wire sample.
8. The correlations calculated tended to support the theory that the amount of relapse was related to the amount of surgical change in the skeletal wire sample only. The correlations for the rigid fixation sample did not support this theory.
9. The correlations did not support the theory that postsurgical relapse was related to the relapse in muscle lengths.

10. Relapse was not greater for those patients that experienced a counterclockwise rotation of the distal segment of the mandible with respect to the proximal segment.
11. The anterior digastric length increased during surgery in both samples, and continued to increase postsurgically in the rigid sample, but relapsed in the skeletal wire sample.
12. The hyoid bone adjusted during surgery by moving anteriorly and inferiorly in both samples. During the follow-up period its position tended to be stable horizontally, but it relapsed superiorly in both samples.
13. A long term alteration of head posture occurred in both samples following surgery. In the rigid sample a forward head posture occurred immediately after surgery. In the skeletal wire sample, the forward head posture occurred during the follow-up period.

CHAPTER VII

CONCLUSIONS

Based upon the cephalometric measurements for the 26 rigid fixation patients and nine skeletal fixation patients evaluated in this study, the following conclusions were reached:

1. The maxilla was very stable both horizontally and vertically for both fixation methods.
2. Rigid fixation produced significantly greater stability in the mandible than did skeletal wire fixation, especially in terms of its ability to maintain rotational control between the proximal and the distal segments.
3. All muscle lengths measured, except the posterior facial height and the anterior digastric, were stretched significantly during surgery and relapsed during the follow-up period. However, the relapse of

muscle lengths did not correlate with relapse of the skeletal segments.

4. A long term change in hyoid bone position and head posture occurred as a result of the surgery.
5. Further investigations are recommended to evaluate the stability of maxillary downgrafting utilizing rigid fixation.

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Publications

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Oral Presentations

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General Practice Residency Thesis Presentation
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